FOREWORD

One of the principal objectives of CANMET's Energy Research Program is to develop the technologies required to conserve and to increase the supply of liquid fossil fuels in Canada to bridge the gap that exists between domestic supply and demand (both internal demand and export opportunities). The Energy Research Laboratories (ERL) responds to this R&D objective on matters related to the upgrading of oil sands, heavy oil and synthetic crude production; coal/bitumen coprocessing; and improved oil and gas domestic heating furnaces. Another major objective is to develop new technologies to burn fossil fuels, mainly coal, under environmentally acceptable conditions and ERL responds to this objective through research in the areas of coal combustion and gasification.

Important input and guidance on project selection and implementation is provided by industry advisory committees and user groups. Shared-cost projects with industry are underway in-house, and major elements are undertaken in the private sector through shared-cost contract R&D programs.

This report summarizes the activities of ERL during fiscal year 1986/87 and is intended as a report to CANMET management and staff and as a working document for preparing the CANMET Review and other branch publications.

After careful consideration and consultation it was decided in 1986 to realign the division's laboratories. A new laboratory, the Fuels Characterization Research Laboratory (FCRL) was created and includes the two analytical groups from the former Hydrocarbon Processing Research Laboratory (HPRL) and the Synthetic Fuels Research Laboratory (SFRL). HPRL's catalysis and separation groups have joined SFRL and HPRL's coal gasification group is now part of the Combustion and Carbonization Research Laboratory.

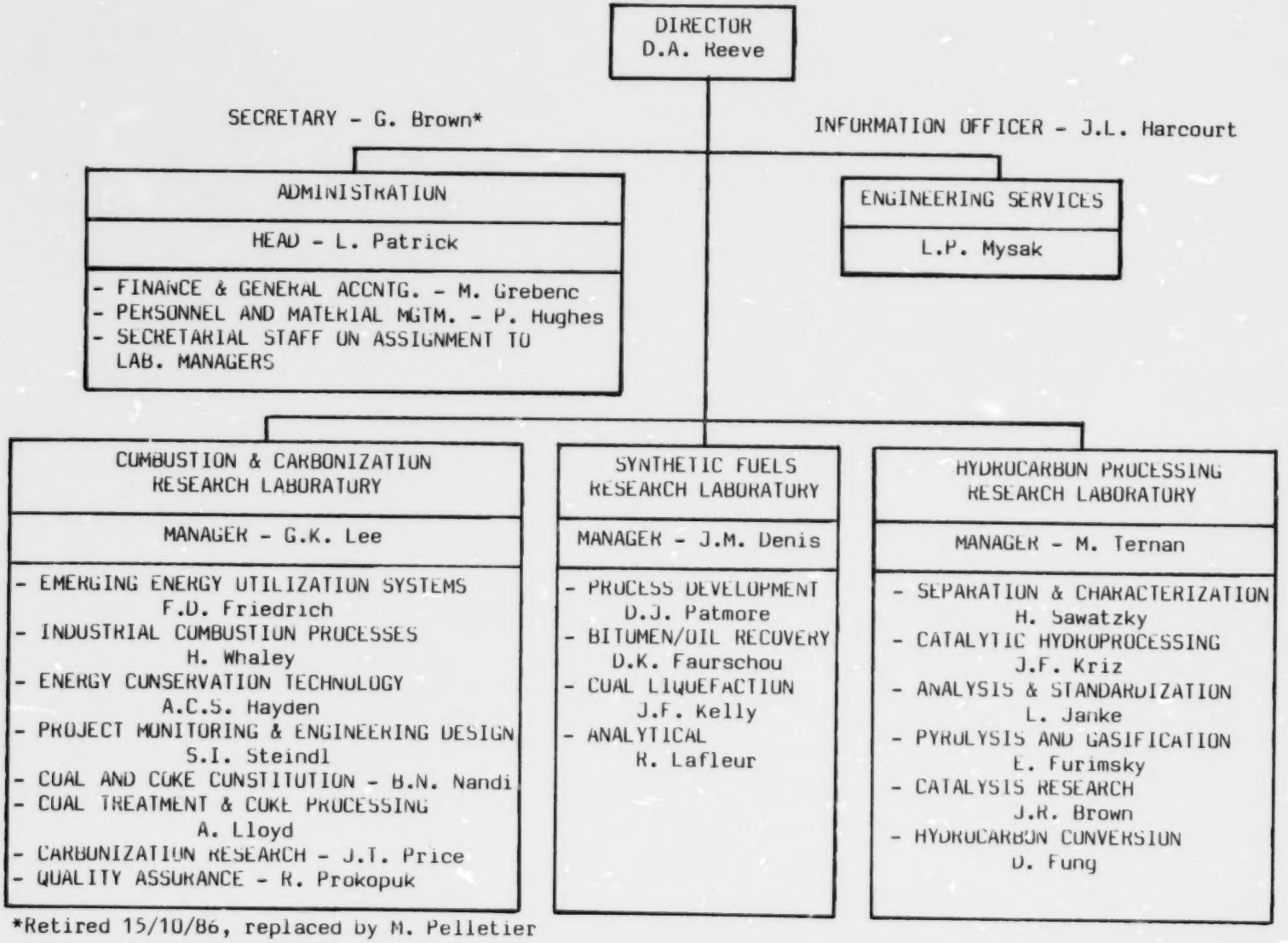
For simplicity in reporting the division's activities for 1986/87 the above realignment in terms of laboratory and section names is not reflected in this report. It is organized according to the laboratories as listed in the resources table given below. However, an organization chart reflecting the division's realignment effective October 27, 1986 is included. Following this realignment and in accordance with requirements for closer contact with client groups and increased industrial relevance, a business plan has been prepared for the division and circulated to staff. The impact of this new approach on divisional programs will be reviewed in future annual reports.

Laboratory	Person Years	Salaries $K	Operating $K	Capital $K	Contracts $K
Synthetic Fuels Research Laboratory	52	1746	731	905	5320
Hydrocarbon Processing Research Laboratory	37	1435	610	865	2621
Combustion & Carbonization Research Laboratory	58	2342	1010	895	2059
Administration	22	852	1049	75	
TOTALS	169	6375	3400	2740	10000

D.A. Reeve

D.A. Reeve
Director
Energy Research Laboratories

ENERGY RESEARCH LABORATORIES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- PROJECT MONITORING & ENGINEERING DESIGN S.I. Steindl
- COAL AND COKE CONSTITUTION - B.N. Nandi
- COAL TREATMENT & COKE PROCESSING A. Lloyd
- CARBONIZATION RESEARCH - J.T. Price
- QUALITY ASSURANCE - R. Prokopuk
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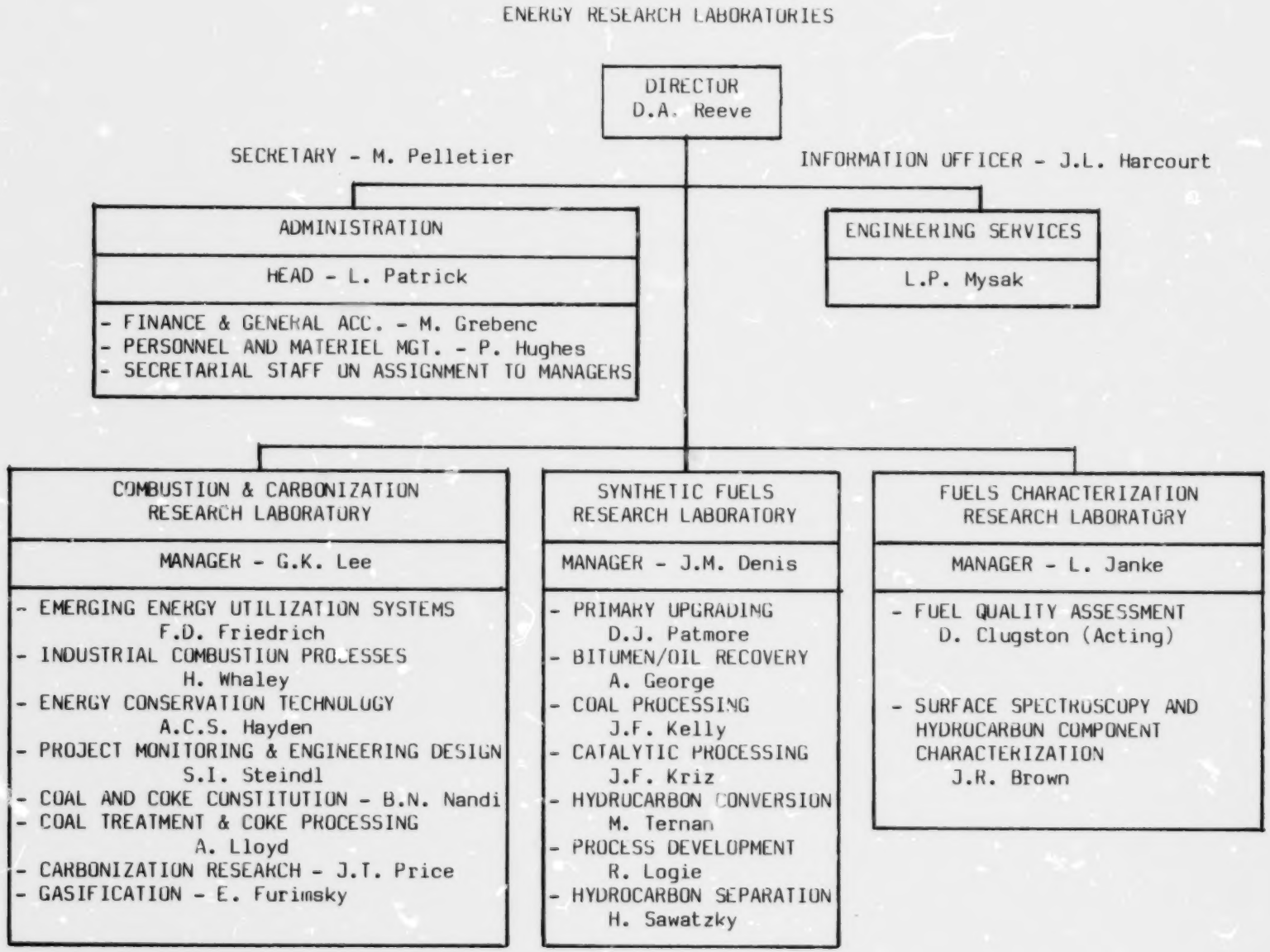
- PROCESS DEVELOPMENT D.J. Patmore
- BITUMEN/OIL RECOVERY D.K. Faurschou
- COAL LIQUEFACTION J.F. Kelly
- ANALYTICAL R. Lafleur
HYDROCARBON PROCESSING RESEARCH LABORATORY
MANAGER - M. Ternan
- SEPARATION & CHARACTERIZATION H. Sawatzky
- CATALYTIC HYDROPROCESSING J.F. Kriz
- ANALYSIS & STANDARDIZATION L. Janke
- PYROLYSIS AND GASIFICATION E. Furimsky
- CATALYSIS RESEARCH J.R. Brown
- HYDROCARBON CONVERSION D. Fung

*Retired 15/10/86, replaced by M. Pelletier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- COAL PROCESSING J.F. Kelly
- CATALYTIC PROCESSING J.F. Kriz
- HYDROCARBON CONVERSION M. Ternan
- PROCESS DEVELOPMENT R. Logie
- HYDROCARBON SEPARATION H. Sawatzky
FUELS CHARACTERIZATION RESEARCH LABORATORY
MANAGER - L. Janke
- FUEL QUALITY ASSESSMENT D. Clugston (Acting)
- SURFACE SPECTROSCOPY AND HYDROCARBON COMPONENT CHARACTERIZATION J.R. Brown

AVANT-PROPOS

Un objectif principal du programme de recherche sur l'énergie du CANMET est de mettre au point des techniques permettant de conserver et d'accroître l'approvisionnement du Canada en combustibles liquides afin de réduire l'écart entre l'offre et la demande en tenant compte du marché national et des possibilités d'exportation. Pour atteindre cet objectif, les Laboratorires de recherche sur l'énergie (LRE) mènent des travaux de R-D dans les domaines suivants: amélioration des sables bitumineux et des pétroles lourds; production de pétroles synthétiques; cotraitment du charbon et du bitume; et amélioration des chaudières de chauffage domestique alimentées au gaz ou au mazout. Un autre objectif d'importance est le développement de nouvelles technologies pour la combustion des combustibles fossiles, surtout le charbon, de façon à ne pas nuire à l'environnement. Les LRE mènent des travaux de recherches à cet effet dans les domaines de combustion et gazéification du charbon.

Des comités consultatifs formés de représentants de l'industrie et de clients des laboratoires aident à orienter le choix et le déroulement des projets. Des projets à frais partagés avec l'industrie sont en cours dans les laboratoires et des travaux importants sont menés dans le secteur industriel dans le cadre de contrats de R-D à frais partagés.

Le présent rapport résume les activités des Laboratoires de recherche sur l'énergie pour l'exercice financier 1986-1987. Ce rapport, destiné à la direction et au personnel du CANMET, constitue aussi un document de travail pour la préparation de la revue du CANMET et d'autres publications de la Direction.

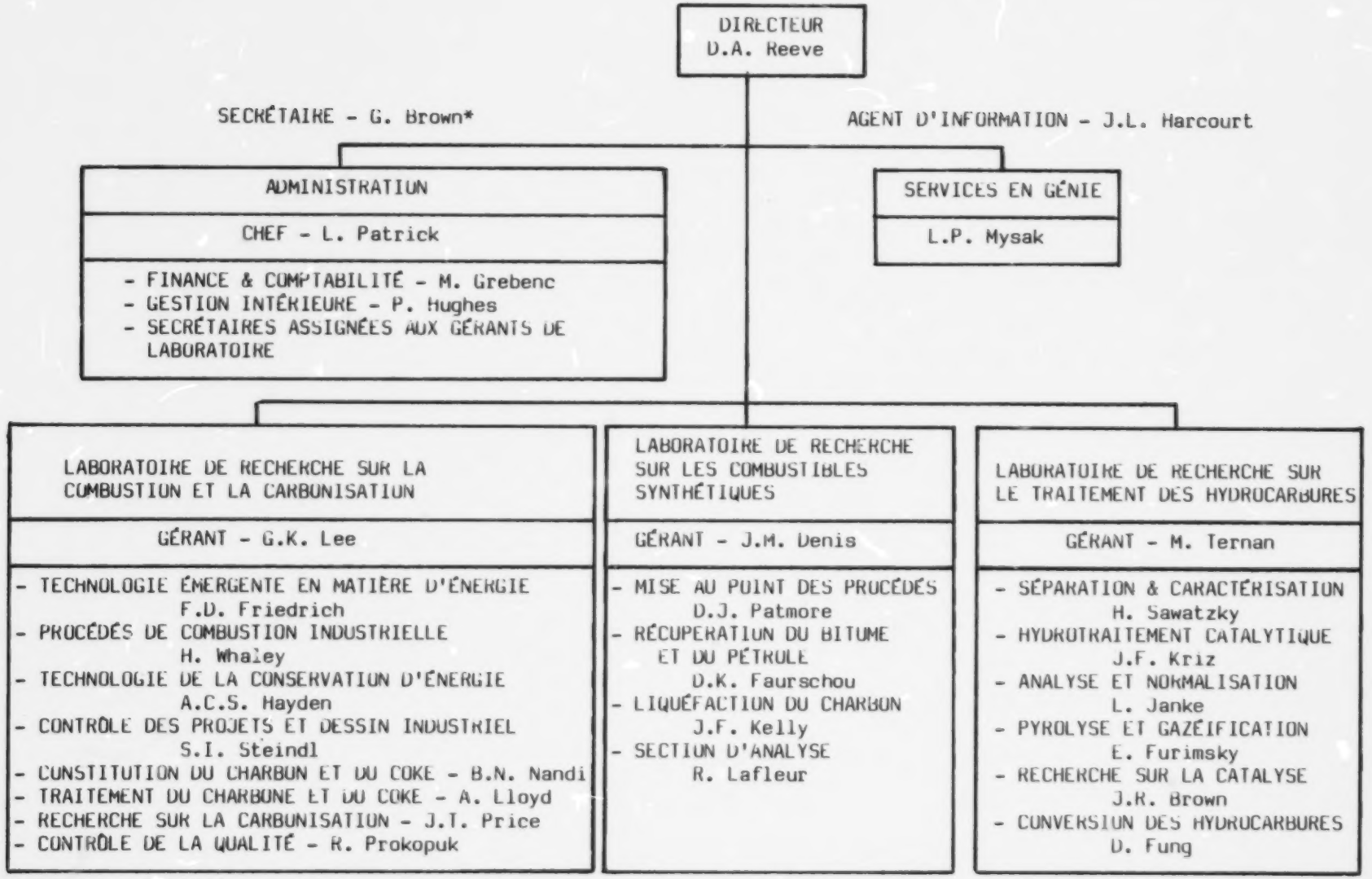
Aprés une consultation et tout bien considéré les laboratoires de la division furent réorganisés en 1986. Un nouveau laboratoire, le Laboratoire de recherche sur la caractérisation des combustibles fût créé et comprend les sections des analyses de l'ancien Laboratoire de recherche sur le traitement des hydrocarbures et du Laboratoire de recherche sur les combustibles synthétiques. Les sections de l'ancien Laboratoire de recherche sur le traitement des hydrocarbures oeuvrant en catalyse et séparation ont rejoint le Laboratoire de recherche sur les combustibles synthétiques tandis que la section de la gazéification du charbon s'est joint au Laboratoire de recherche sur la combustion et la carbonisation.

Afin de simplifer ce présent rapport des activités de la division pour 1986-87, on ne tiendra pas compte de la réorganisation décrite ci-dessus. Le rapport est compilé selon les laboratoires comme démontré dans la table-ressources ci-dessous. Cependant, un organigramme réflétant la réorganisation de la division depuis le 27 octobre 1986 est inclus. A la suite de cette réorganisation et conformément aux engagements d'établir des contacts plus étroits avec les clients et d'accroître la pertinence des projets face aux besoins de l'industrie, un plan d'opérations a été préparé pour la division et distribué au personnel. L'impact de cette nouvelle approche sur les programmes de la divison sera analysé lors des futurs rapports annuels.

Laboratoire	Année-Personne	Salaires $K	Exploitation $K	Immobilisation $K	Contrats $K
Laboratoire de recherche sur la combustion et la carbonisation	52	1746	731	905	5320
Laboratoire de recherche sur les combustibles synthétiques	37	1435	610	865	2621
Laboratoire de recherche sur le traitement des hydrocarbures	58	2342	1010	895	2059
Administration	22	852	1049	75	
TOTAUX	169	6375	3400	2740	10000

D.A. Reeve
Directeur
Laboratoires de recherche sur l'énergie

LABORATOIRES DE RECHERCHE SUR L'ÉNERGIE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- PROCÉDÉS DE COMBUSTION INDUSTRIELLE H. Whaley
- TECHNOLOGIE DE LA CONSERVATION D'ÉNERGIE A.C.S. Hayden
- CONTRÔLE DES PROJETS ET DESSIN INDUSTRIEL S.I. Steindl
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- TRAITEMENT DU CHARBONE ET DU COKE - A. Lloyd
- RECHERCHE SUR LA CARBONISATION - J.T. Price
- CONTRÔLE DE LA QUALITÉ - R. Prokopuk
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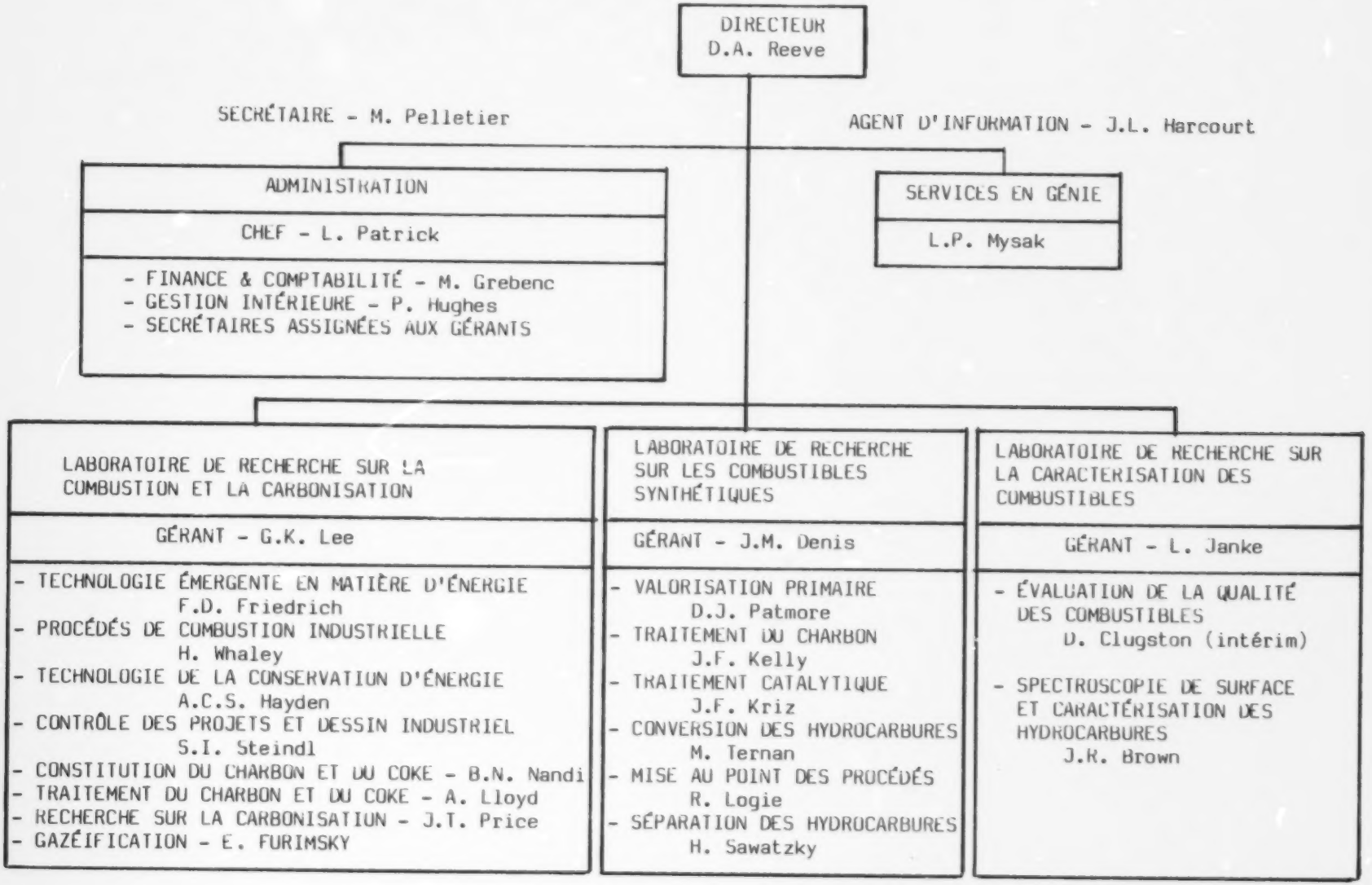
- HYDROTRAITEMENT CATALYTIQUE J.F. Kriz
- ANALYSE ET NORMALISATION L. Janke
- PYROLYSE ET GAZÉIFICATION E. Furimsky
- RECHERCHE SUR LA CATALYSE J.R. Brown
- CONVERSION DES HYDROCARBURES D. Fung

*Retraitée 15/10/86, remplacée par M. Pelletier

LABORATOIRES DE RECHERCHE SUR L'ÉNERGIE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J.F. Kriz
- CONVERSION DES HYDROCARBURES
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- MISE AU POINT DES PROCÉDÉS
R. Logie
- SÉPARATION DES HYDROCARBURES
H. Sawatzky
LABORATOIRE DE RECHERCHE SUR LA CARACTÉRISATION DES COMBUSTIBLES
GÉRANT - L. Janke
- ÉVALUATION DE LA QUALITÉ DES COMBUSTIBLES
D. Clugston (intérim)
- SPECTROSCOPIE DE SURFACE ET CARACTÉRISATION DES HYDROCARBURES
J.R. Brown

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PART I

SYNTHETIC FUELS RESEARCH LABORATORY

PART I

SYNTHETIC FUELS RESEARCH LABORATORY

HIGHLIGHTS

Synthetic fuels produced from Canadian low-grade energy resources such as coal, bitumen, heavy oils and refinery residues are gaining increasing importance as world reserves of conventional crude diminish. During 1986/87, the Synthetic Fuels Research Laboratory (SFRL) continued its lead role in R&D activities related to the production of synthetic fuels suitable for transportation and residential heating. These in-house activities were complemented by cooperative projects with industry, universities, provincial agencies and the US Department of Energy, consisting of 41 ongoing contracts.

The in-house and contracting-out projects were carried out by 52 full-time employees including 15 research scientists, 34 technologists and 3 chemists. The employees generated a high level of output as follows: 6 patents were granted, 38 research reports were written, 9 research reports were published in outside journals and 10 technical presentations were given at conferences.

The SFRL budget for 1986/87 was allocated as follows:

	$K
Salaries	1746
Operating	731
Capital	905
Contracts	5320
TOTAL	8702

In the recovery of bitumen and heavy oil, SFRL, through its contracting-out program supported critical gap, generic R&D which complements or shares risks with industry and other agencies. Of particular importance was the participation with AOSTRA and industry in a horizontal well steam pilot project at the AOSTRA Underground Test Facility. Also, under a Canada/US Memorandum of Understanding, contracts were supported to develop a program for a study of the use of non-condensable gas additives with steam for in-situ recovery of bitumen and heavy oil.

SFRL has developed a strong expertise in slurry hydrocracking through research into the fundamentals of this technology. A novel dual energy densitometer for rapid ash determination has been developed jointly by SFRL/AECL. This instrument has considerable potential for commercial application in the petroleum industry. The CANMET Hydrocracking Demonstration Plant in Petro-Canada's Montreal refinery continued operations and was able to achieve successfully high conversions at design throughputs. SFRL supported the demonstration activities by trouble-shooting operating problems and monitoring reactor performance. Significant advances have been made in simplifying the additive preparation to make the process more commercially attractive.

R&D activities were continued in coprocessing (simultaneous processing of coal and bitumen/heavy oil) by examining the performance of Eastern Canadian high-volatile bituminous coals. Results indicate that bituminous coking coals are more difficult to process than Western Canadian subbituminious coals because of problems associated with their thermophysical behaviour.

A techno-economic study was completed in which CANMET coprocessing was compared with CANMET hydrocracking. The study showed that coprocessing was always slightly less economical than hydrocracking and that coprocessing technology requires further improvement in a number of areas to be competitive.

The Nova Scotia Research Foundation (under contract) investigated two-stage liquefaction of Nova Scotia coals. The coal conversions averaged 91 wt % and a net yield of 67 wt % was achieved with Prince Hub coal. These results are comparable to those obtained previously at the Wilsonville plant using Illinois No. 6 coal.

A Canada/Japan joint technical meeting on coal liquefaction was held in Japan. The Japanese presented the test results on five low-rank Canadian coals. Efforts continue to ensure testing of Canadian coals in a proposed 250 t/d unit.

BITUMEN AND OIL RECOVERY SECTION

DEVELOPMENT OF NEW TECHNOLOGY FOR RECOVERY OF ATHABASCA BITUMEN

The Athabasca reservoir is one of the largest oil sand deposits in the world and constitutes 75% of the oil sand reserves in Alberta. The Athabasca surface mineable reserves are equivalent, depending on oil prices, to about three times those of conventional crude oil in Western Canada. Production of synthetic crude oil from these reserves could more than offset declining oil production in Alberta. However, recovery operations based on mining must compete with stimulated in situ recovery of heavy oil and bitumen, enhanced recovery of conventional oil and production from arctic and east coast offshore reservoirs. The need for a better process for extraction of bitumen from mined oil sands has been identified as a critical gap requirement. On the other hand, only 7% of the Athabasca reservoir is potentially amenable to surface mining techniques now employed commercially. In situ production technology is inherently more compatible than that of Suncor and Syncrude with phased incremental production of bitumen and heavy oil and therefore deserves special attention during this decade.

CANMET is contributing to the development of new technologies for bitumen recovery, i.e., extraction from mined oil sands and in situ production through participation with AOSTRA and industry in field testing and demonstration as follows:

(1) UMATAC (Taciuk) Process

CANMET was prepared to participate in field demonstration of this thermal process for extraction and partial upgrading of bitumen from mined oil sand. Because of the present slump in world oil prices, negotiations were not successful during 1986 to attract industrial participation in this technology. The large scale demonstration of the Taciuk thermal process is now in a holding pattern. However, CANMET is interested in supporting smaller scale projects for the utilization of this technology to extract bitumen from sludges and residual petroleum wastes. New processes are monitored continuously to identify areas for funding to advance the extraction technology.

(2) Horizontal Well Gravity Drainage Technology

CANMET is cooperating with AOSTRA and industry in the development and field trials of novel concepts of horizontal well in situ steam recovery technology at the AOSTRA Underground Test Facility (UTF) in the Fort McMurray area of the Athabasca deposit. This three-year prepilot program utilizing horizontal wells should also be of particular relevance to in situ recovery from the thin heavy oil reservoirs of Saskatchewan. Horizontal wells may be the only way to achieve major commercial in situ recovery from the Athabasca deposit or marginal heavy oil reservoirs.

CRITICAL GAP IN SITU RECOVERY R&D

Bitumen and heavy oil resources, which are only accessible by in situ technology, are an order of magnitude larger than surface mineable ones and are therefore of world-wide interest.

New commercial operations in the oil sands utilize steam stimulation processes and generally produce from prime reservoirs. The economic risks are significantly lower, at every stage of development, than current mining technology because production revenues during incremental scale up provide ongoing capital and tax allowances.

Although commercial in situ operations exist for recovery of bitumen and heavy oil the technology is in the early development stage. Critical gap, novel and generic research is required for reservoir characterization to match reservoirs with processes having a high probability of success; physical and numerical modelling to evaluate process concepts and sensitivities and to predict and monitor production performance; evaluation of steam additives and how they may be used to enhance sweep efficiency by displacing fluids; development of both thermal and non-thermal in situ processes for heavy oil reservoirs which are generally marginal because of thinness, presence of bottom water and gas caps; development of thermal in situ processes for the Athabasca resources which, although characteristically thick with high bitumen saturation, are intractable because they have virtually no dissolved gas and are impermeable until the bitumen has been heated; compatibility of injected fluids with reservoir fluids and minerals; development of communication for injected fluids between wells in bitumen reservoirs; fracturing of unconsolidated oil sand reservoirs; more economic technologies for

generation of steam; and remote monitoring of the spatial distribution of induced fractures, injected fluids and displaced oil so that in situ processes may be monitored and controlled.

CONTRACTS

1. "Steam injection experiments in scaled physical models for simulating marginal heavy oil reservoirs - Phase II"

A low pressure scaled simulator was designed and constructed to verify operational performance in the simulation of enhanced oil recovery from marginal heavy oil reservoirs. Development of a numerical simulator for use with the physical simulator was initiated. Several steam injection strategies were tested for application to Lloydminster-type heavy oil reservoirs characterized by thin pay zones, and bottom water or gas caps. Favourable results were obtained.

2. "Numerical simulation of steam injection in bitumen and heavy oil reservoirs - Phase II"

Conventional static grid systems are both inefficient and not well suited for application to in situ recovery in the presence of vertical fractures or use of horizontal wells. Methodology for dynamic front tracking of frontal zones has been developed. The second phase of the work aims at formulating a three-dimensional, steady-state numerical simulator with the specific purpose of simulating the horizontal well gravity drainage process.

3. "Evaluation of steam additives and clay stabilizers for enhanced heavy oil processes"

The objective is to improve the recovery of heavy oil from reservoirs in Alberta and Saskatchewan. Frequently these reservoirs fail to produce at commercially acceptable rates due to impairment of reservoir permeability. The experimental work is elucidating the role of steam additives and clay stabilizers in preserving reservoir permeability, enhancing fluid injectivity and maintaining oil production. Studying the interactions of these additives and stabilizers is an important goal.

4. "Steam recovery processes with the addition of non-condensible gases - mechanistic study"

The objective of this contract, carried out under the auspices of the Canada/US Memorandum of Understanding for Cooperation in R&D on Oil Sands and Heavy Oil, is to identify mechanisms whereby the addition of non-condensible gaseous additives could improve steam recovery processes. A special displacement apparatus is used to alleviate many of the experimental problems encountered in these types of experiments.

5. "Impact of drilling and completion fluids on the productivity of heavy oil recovery processes"

This project was undertaken to investigate the extent to which fluids used in the drilling and completion of heavy oil wells interact with the formation to reduce permeability and create wellbore damage. The objective is to optimize productivity from the in situ heavy oil reserves of Western Canada.

COOPERATIVE GENERIC R&D WITH AOSTRA, OTHER PROVINCES AND THE US

Canada and the United States signed a Memorandum of Understanding for Cooperation in R&D on Oil Sands and Heavy Oil in 1979. The US participates through its Department of Energy. The Canadian participants are Energy, Mines and Resources Canada (CANMET), the Saskatchewan Department of Energy and Mines and the Alberta Oil Sands Technology and Research Authority (AOSTRA). Relevant implementing agreements are:

a) resource characterization,
b) steam additives in bitumen/heavy oil recovery,
c) exchange of information,
d) remote sensing of frontal movements of steam in in situ recovery process.

Such activities promote awareness of mutual interests in critical gap and generic R&D needs and facilitate exchange of information at a senior research and policy influencing levels.

CANMET also contributes by consultative scientific/technical advice, evaluation and direction via the Management Committee of the Canada-Saskatchewan Heavy Oil/Fossil Fuel Agreement for research conducted or subcontracted by the Petroleum Division of the Saskatchewan Research Council and for contracts by Saskatchewan Energy and Mines to industry for research and field testing/demonstration programs. The agreement was allotted up to $30M and a term to March 1988.

PROCESS DEVELOPMENT SECTION

FUNDAMENTAL STUDIES AND DEVELOPMENT OF UPGRADING PROCESS FOR BITUMEN, HEAVY OILS AND RESIDUA

The effect of operating parameters on flow regime transitions in hydrogen/hydrocarbon bubbling multiphase flows was quantified at elevated temperatures and pressures at different reactor positions using gamma-ray interrogation techniques. Similar scanning gamma-ray interrogation methods were used to measure attenuation coefficients of fluids in the pilot plant reactor at process conditions. These data were then used for the quantitative determination of void fractions during hydrocracking in CANMET's demonstration plant. Reports on correlation of voidage with gas rate and the use of gamma densitometry were completed.

The development of a model using a spectrum of kinetic rate constants was initiated in order to describe the conversion of pitch in the CANMET hydrocracking process.

A modified axial dispersion sedimentation model was used to predict solids concentration profiles in three-phase bubble columns. Simulation results agreed very well with experimental data obtained from a cold model bubble column. Based on this model, predictions were made of the solids behaviour in the CANMET hydrocracking demonstration plant.

As part of a study of the coking propensity of heavy feedstocks, a hot-stage micro-reactor was calibrated at hydrocracking temperatures and pressures and commissioned with heavy oil, heavy oil components and coal in the presence of iron and tin catalysts. A basis for using the techniques to screen feeds and additives is evolving after equipment problems were solved and important procedural changes implemented.

A pilot plant experimental program to measure vapour/liquid equilibrium at process conditions was completed and a correlation of observed data with predictions from computer simulations was initiated.

As an initial phase in assessing the potential applications of ultra-sound to heavy oil upgrading, the efficiency of a custom designed ultrasonic generator for use at high temperature and pressure was measured and found to be superior to a standard unit.

ERL's nuclear magnetic resonance (NMR) program was supported by providing expertise and supervision of projects for other sections. Major collaborative projects included studies of coal weathering by solid state C-13 NMR, hydrogen donor ability of coprocessing feeds and cetane values by C-13 NMR. Advice was given on equipment and liaison between ERL and Varian research scientists was continued.

Studies on the heat of hydrocracking reactions were completed using a specially designed continuous stirred tank reactor in one of the hydrocracking pilot plants. Detailed analyses of the results were reported.

A novel dual energy densitometer was developed by EMR and Atomic Energy of Canada Ltd. (AECL), and a prototype commercial unit was constructed under contract by AECL. The densitometer provides analysis of ash of heavy oil process streams and other materials within 15 min. compared with 8 h using the standard ASTM method. It has considerable potential for commercial application in the petroleum and other processing industries.

CONTRACTS

1. "High temperature electron paramagnetic resonance (EPR) studies of the thermolysis of heavy oil and its components"

Free radicals are known to be involved in hydrocracking processes. Spin trapping techniques have identified carbon, sulphur and oxygen centred radicals generated from the thermolysis of heavy oil, maltenes and asphaltenes. This information will aid in understanding the fundamentals of hydrocracking processes.

2. "Residence time distribution in model three-phase flow columns"

A newly built steel 60-cm column was used to measure gas holdups and liquid dispersion coefficients and to verify the dependency of the liquid dispersion on column diameter. The effect of pressure on gas holdup and liquid mixing was determined in a 15-cm pressure column and an investigation was begun on the hydrodynamics of foaming hydrocarbon systems in a 30-cm glass column.

3. "Kinetic studies of coke formation in heavy oil fractions"

A study of the rate of coke formation from heavy oil components in the presence of hydrogen was completed. The rate of coke formation was considerably less than in the absence of hydrogen, and increased in the order aromatics, resins, and asphaltenes.

4. "Rapid pyrolysis of feed and hydrocracked pitch"

A contract to study the fast pyrolysis of hydrocracked pitch was completed. The results indicated that fast pyrolysis is not likely to prove useful for the treatment of residual pitch from high conversion hydrocracking processes, but could be suitable for mild upgrading for viscosity reduction of heavy oils.

5. "Biotechnological methods for upgrading of bitumen, heavy oil and residuals"

The potential of biotechnological techniques for upgrading heavy oil is being assessed. Experiments on microbial desulphurization and viscosity reduction are now underway. Initial results on the evaluation of growth parameters for the microorganisms appear promising.

PROCESS DEVELOPMENT OF HYDROCRACKING TECHNOLOGY

Numerous additives were screened in an autoclave at hydrocracking conditions for hydrogen consumption, yield and conversion. Variations in the chemical and physical properties of the iron significantly improved the additive and provided options for new, large scale additive preparations, as well as opportunities for improving the CANMET hydrocracking process.

Microscopy of pilot plant samples was conducted and the composition and morphology of the solids present were correlated with process conditions. Sample preparation techniques were modified to enable rapid, real time analysis required for commercial application. A report was completed on the microscopic analysis of demonstration plant samples.

A study of hydrogen consumption during hydrocracking of heavy oils was instrumental in helping to assess the role of the CANMET hydrocracking additive as a coke inhibiting agent.

SUPPORT OF THE COMMERCIALIZATION OF THE CANMET HYDROCRACKING PROCESS

Four pilot plant runs simulating demonstration plant conditions and additives were performed. Valuable information was generated for operation of the plant. Personnel were seconded to the plant to monitor and advise Petro-Canada on operation during commissioning runs. ERL scientists, particularly those on site, played an important role in ensuring successful operation of the unit by advising and assisting Petro-Canada on reactor behaviour, hydrodynamics of multiphase flow, solids microscopy, analysis and sampling.

COAL LIQUEFACTION SECTION

ADVANCED COAL LIQUEFACTION RESEARCH

The objectives are to investigate novel or advanced coal liquefaction approaches through fully-funded and shared-cost contracts, and to maintain national awareness of latest coal liquefaction technology. Modified direct coal liquefaction technology and advanced pyrolysis processes could reduce synthetic fuel costs and meet future Canadian energy needs. Recognizing the need for long lead times for implementation and human expertise, CANMET will foster small-scale R&D projects for future demonstration of this strategic technology. CANMET will also help maintain national awareness of work carried out in Japan, US, Germany, and Britain.

A large number of Canadian coals have been tested under the Canada/Japan Science and Technology Consultation Agreement of May 1986 at Japanese liquefaction facilities which includes a 1 t/d process development unit.

SHARED-COST CONTRACTS

1. "Liquefaction of Nova Scotia Coals - Phase VII"

Bench-scale studies were carried out on integrated two-stage thermal/catalytic liquefaction of Sydney area coals. Two conventional hydroprocessing catalysts, Katalco 550 and Amocat 1C, were tested in the second-stage reactor. Eighteen experiments were conducted in a once-through process mode using hydrogenated anthracene oil. The coals tested were Lingan Harbour, Prince Hub and Donkin Harbour. Coal conversions of 92-95 wt % were achieved with both catalysts. In terms of oil yields the order of reactivities of coals were Prince Hub, Donkin Harbour, Lingan Harbour.

After the exploratory tests, a six-day recycle liquefaction run was conducted with Amocat 1C using Prince Hub coal. Conversion averaged 91 wt % over the last 12-h operating period. The net C_4+ liquid yield was 67 wt % based on maf coal plus hydrogen. High yields of light and middle distillates were achieved and naphtha and light gas oil yields were 44 and 38 wt % respectively.

The next phase will concentrate on process optimization, coal reactivity and catalyst evaluation studies. Work is planned on recycle liquefaction of Prince Hub coal after which the first-stage thermal dissolver will be converted to a catalytic dissolver. Following this, a test program will be undertaken on catalytic two-stage liquefaction of coals from the Sydney area.

2. "Agglomeration and Liquefaction of Hat Creek Coal"

Previously it was demonstrated that more than 90% of the calorific value of raw Hat Creek coal, which contains between 30 and 40% ash, can be converted to saleable liquids and gases by direct liquefaction technology using donor solvent. The objectives of this project were to optimize spherical oil agglomeration process parameters specific to Hat Creek coal, to produce a small quantity of deashed coal by spherical oil agglomeration, and to perform coal liquefaction of agglomerated coal. CANMET, B.C. Hydro, and B.C. Ministry of Energy, Mines and Petroleum Resources funded this project, and the Alberta Research Council undertook the oil agglomeration task and B.C. Research Council performed the liquefaction of agglomerated coal. Results of the experiments were presented at the joint technical meeting of Canada/Japan Coal Liquefaction Cooperative Program in order to promote this coal to Japan.

FULLY-FUNDED CONTRACTS

1. "Techno-economic comparison of the Sandwell Centrax solid-liquid separation process with the Kerr-McGee critical solvent deashing process as part of an integrated two-stage liquefaction process"

A technical evaluation of the Centrax deashing process under development by Sandwell Technologies was completed. This was accomplished by analyzing process results obtained from both laboratory- and bench-scale prototype equipment. A conceptual direct coal liquefaction plant has been designed incorporating the Centrax process and costs of liquid products from the plant have been estimated using the MITRE Coal Liquefaction Cost Model. These costs have been compared to those obtained using the Kerr-McGee critical solvent deashing (CSD) process as an alternative deashing system. Wilsonville liquefaction runs 244 and 250 have been used as the basis for the conceptual commercial plants. Run 244 was operated in an integrated two-stage liquefaction (ITSL) mode while run 250 uses a reconfigured integrated two-stage liquefaction (RITSL) mode where the deasher is placed after the hydrotreater. Both runs used Illinois #6 coal as feedstock.

2. "Flash hydropyrolysis of Eastern Canadian Coals"

It was discovered earlier that the continuous operation of a flash hydropyrolysis (FHP) reactor with Eastern bituminous coal feeds is impossible because of their caking nature. A new process was developed that ensures the smooth continuous operation of the FHP reactor using caking bituminous coals. The process was proved and a patent application was initiated.

COPROCESSING

Research and Development

The objectives of this project are to investigate the concept of simultaneously processing slurries of coal and vacuum bottoms/heavy oils and to develop a potentially marketable Canadian process. Coprocessing has been investigated at ERL as an extension of the CANMET hydrocracking technology. The CANMET coprocessing concept has generated considerable national and international interest in recent years. In Eastern Canada, the combination of Maritime bituminous coals with conventional crude residues or imported heavy oils offers potential for large-scale applications. In Western Canada, the process allows upgrading low-rank plains coals with indigenous tar sand residues or heavy oils. Several experimental tasks are carried out at ERL at three levels of equipment complexity: the investigation of fundamental concepts using batch autoclave reactors, the application of the concept to continuous operation using two bench-scale units, and finally the confirmation of long term operability using a pilot plant.

Experimental Program

Novel reactor concept

A new operational concept for coprocessing using two different types of catalysts in a well mixed reactor has been investigated. Studies of gas phase residence time and distillate product improvement have been carried out. After further studies a patent application will be prepared to cover novel features of the concept.

Solvent/coal compatibility

Four coals and four bitumens/heavy oils were selected to investigate the effect of solvent/coal combination on process performance and yield structure in coprocessing. The feedstocks have been characterized and coprocessing experiments are underway. Process performance and product yields will be correlated to the characteristics of the feedstocks.

Micro-continuous coprocessing unit

The construction of a micro-continuous coprocessing unit was begun. A novel syringe pump was constructed which is capable of delivering coal-heavy oil slurries containing high coal concentration. Preliminary testing of the internal mixing with a slurry containing 40 wt % maf coal indicated that good mixing can be achieved in the barrel of this pump.

Characterization of coprocessing products

Effect of coal concentration on product distribution in coprocessing was studied using high performance liquid chromatography (HPLC), field ionization mass spectrometry (FIMS), 13C and 1H nuclear magnetic resonance (NMR) spectrometry techniques. Increasing coal

concentration from 4 to 24 wt % resulted in a slight increase in polar fraction with a corresponding decrease in the saturated fraction. Meanwhile the molecular weights of all fractions decreased as coal concentration was increased. The yield of mono and poly aromatic fractions did not change. Other techniques such as isotopic mass balance measurement has been applied to determine the contribution of coal-derived liquids into the distillate fraction.

Process options to increase pitch conversion

Experimental work on the effect of temperature distribution in a single stage coprocessing reactor was performed in a continuous bench-scale tubular reactor. Two to three distinctive temperature zones were created by the insertion of perforated plates into the reactor. The feed residues used in the experiments were artificially cut at very high boiling point (525°C+) and proved to be extremely viscous. It was shown that the CANMET method could process such an extremely heavy feedstock as well. Detailed analysis is in progress.

Rheology of coprocessing fluids

Experimental work was initiated to investigate the rheology of coal-vacuum bottoms at atmospheric pressure and moderate temperatures using the Searle system (cup and rotor type) viscometer. The effects of various parameters such as coal concentration, coal particle size, operating temperature and shear rate were investigated. Experimental work was completed and data analysis is in progress.

An experimental system developed for coal liquefaction by Sandia National Laboratories, New Mexico, USA was identified as the best unit to be modified for investigating reactive coal-bitumen rheology. A unit was manufactured and commissioned successfully at elevated pressures and moderate temperatures.

Thermodynamic properties of coprocessing distillates

Experimental data on the vapour pressure and vapour-liquid equilibrium of hydrocarbon fractions produced by the coprocessing of coal and oil constitute essential information for the design of coprocessing facilities. An experimental assembly was modified to ensure the safety of operating personnel. Experimental work was carried out using mixtures of various coprocessing distillate fractions. The results were analyzed and a method of predicting vapour-liquid equilibrium at any temperature and liquid compositions was established.

Coprocessing of high-volatile bituminous coals - continuous-flow tests

A report was completed on the assessment of Eastern Canadian high-volatile bituminous coals as coprocessing feedstocks. The report includes a description of the procedures adopted to overcome the problems associated with the thermophysical behaviour of these coals. It also includes a comparison between the behaviour of bituminous coals and that of low rank coals under similar processing conditions.

Three bituminous coals, one from the United States and two from Eastern Canada, were processed at a range of operating conditions. A report on the performance parameters of the three coals is under review.

Coprocessing of high-volatile bituminous coals - batch autoclave tests

A hot charge batch autoclave unit was used to study the effect of additive level and additive distribution on the performance of three high-volatile bituminous coals: Illinois #6 from the United States, Prince mine and Lingan mine from Eastern Canada. The study also included a comparison of the behaviour of low-rank coals. A report is in preparation.

Effect of additive concentration on coprocessing performance

The continuous-flow stirred tank reactor unit was used to test the effect of additive concentration on the coprocessing performance of Forestburg subbituminous coal and Cold Lake vacuum bottoms. Three concentration levels were tested. The analytical results are being compiled.

CONTRACTS

1. "Physical and chemical changes in treated coals and coal slurries"

The effect of additives on coal properties is being studied. The properties to be examined are dilatation characteristics, fluidity, surface area, porosity and coking propensity of the coals as well as the coking propensity of the coal/heavy oil slurries.

2. "Mathematical modelling of coprocessing kinetics"

A mathematical model of coprocessing reaction is being developed based on the processing data generated at CANMET. The model will allow the identification of the significant reaction steps and the determination of the corresponding rate constants and activation energies. The model will also be tested using processing data generated at different conditions and using different feedstocks.

3. "Evaluation of atmospheric flash pyrolysis of coprocessing residues"

The feasibility of producing liquids from coprocessing non-distillable products (+525°C material) by fluid bed atmospheric flash pyrolysis was examined. The agglomeration of the residues presented operational problems in the fluid bed reactor. A spouted bed reactor was also tested. Although the operability was better than that for the fluid bed reactor, long duration performance could not be achieved. Data were collected using the spouted bed configuration. A final report is in preparation.

4. "Techno-economic study of CANMET coprocessing technology - 20,000 bbl/day syncrude from Cold Lake crude"

A techno-economic feasibility study of small-scale plants to upgrade Cold Lake crude by either CANMET coprocessing or hydrocracking was completed. The study compared two coprocessing cases with hydrocracking in terms of estimated available price per tonne of feedstock (coal plus crude oil). The available feedstock price was calculated from gross revenue less operating costs and capital charge. Sensitivity tests were carried out on natural gas price, product value, rate of return and capital cost. The results are confidential.

5. "Investigation of the use of spherical oil agglomeration in the beneficiation of low-rank Canadian coals as an integrated part of CANMET coprocessing technology"

High ash content in low-rank Canadian coals reduces net oil yields when used as coprocessing feedstocks. A unique technology to address this problem was conceived and demonstrated experimentally. A patent has been applied for.

6. "Exploratory investigation of solids removal from CANMET coprocessing residues"

Novel concepts for the removal of solids from CANMET coprocessing residues are being explored.

7. "Coal preparation technology for CANMET coprocessing"

A work statement was proposed for the subject contract which will be undertaken next fiscal year. The major objective is to identify optimum coal preparation flowsheets for CANMET coprocessing to reduce overall process costs.

ANALYTICAL SECTION

The Analytical Section provides analytical services for petroleum, petroleum type products and coal liquids used and generated in ERL's research pilot plants. Products range from bitumens and heavy oil residual fractions to light distillates, naphthas and hydrogenation product gases. Materials such as catalysts, shales, biomass materials and residues are also analyzed.

Analyses are done in five general areas:

(a) elemental analysis (C, H, N, O, S, and metals),

(b) standard product tests as performed routinely in industry, e.g., ASTM test methods,

(c) separations by distillation or chromatography,

(d) chemical component analysis (GC, GC/MS, NMR, etc.),

(e) gas analysis (hydrogenation recycle gases).

SUMMARY

About 17 000 analyses on approximately 5000 samples were performed. Most of the work was carried out in direct support of ERL in-house research projects. About 7% was conducted under collaborative interlaboratory programs and for industry, government departments, universities and research laboratories. Analytical services totalling $837.2 K were provided based on typical commercial rates.

IN-HOUSE RESEARCH PROJECTS

Work involved analytical support of bitumen processing (48%) with most of that effort to satisfy the requirements of the CANMET hydrocracking pilot plant (39.5%) and the rest (8.5%) to research in catalytic hydroprocessing and characterization of bitumens and distillate products.

The coal research programs received 45% of the section's efforts, essentially in support of research in coprocessing. The CCRL combustion research programs received 2.5%.

OUTSIDE ACTIVITIES

An important part of the section's efforts involves collaboration in interlaboratory testing programs. These interlaboratory tests are necessary to maintain a high level of quality in the precision and accuracy of the analyses performed by the laboratory. The section collaborates in the CGSB Cooperative Fuels and Lubricants Monthly Exchanges and in other interlaboratory programs. Interlaboratory tests conducted in 1986 in which the section participated included ASTM round-robins on determination of heat of combustion of middle distillate and jet fuels and simulated distillation of crude oils.

Personnel also participated in the activities of the CGSB and ASTM, two standards writing organizations which are involved in preparation of specification standards and standard test methods for petroleum products. A project was undertaken to determine the heats of combustion of various petroleum fuels and to compare the experimentally determined values with those estimated using different empirical estimation equations. The results were presented to both the CGSB and ASTM. Another project involved the coordination of a round-robin to estimate cetane number of middle distillates by NMR. A report will be presented to the CGSB in the coming year.

Analyses were performed for a number of outside clients, mainly CANMET's Mining Research Laboratories, other government departments and crown corporations (NRC, DND, DPW, Environment Canada, Consumer and Corporate Affairs, Transport, etc.) and for the New Brunswick Electric Power Commission under the terms of the contract with NBEPC. These outside activities represented about 7% of the output.

NEW DEVELOPMENTS 1986

A new instrument was obtained for high temperature simulated distillation of crude oils and residues. Simulated distillation can now be performed to a maximum of 800°C.

The new NMR instrument (300 MHz) was brought into service this year and by August 1986 regular Carbon-13 and proton NMR analyses were regularly provided for coals and liquid fuels.

A computer system for analytical data management was installed in the summer 1985 and the Laboratory Information Management System (LIMS) database system became operational in January 1986. The database system manages the large amounts of analytical information generated and provides reports in a more effective and timely manner.

A research contract for the development of a rapid GC/MS method for the determination of the various saturate and aromatic hydrocarbons in petroleum middle distillates was completed. This method, to support research in upgrading of synthetic crudes, is expected to be available for routine analytical services in the next year.

ANALYTICAL SERVICES/BREAKDOWN BY CLIENT - 1986

Client	No. of Samples	No. of Analyses	Cost ($K)
Synthetic Fuels Research Laboratory			
Process Development Section	2 159	8 100	330.7
Coal Liquefaction Section	1 768	4 948	354.3
Analytical Section Collaborative Tests	43	179	5.8
Hydrocarbon Processing Research Laboratory	682	1 509	70.9
Combustion and Carbonization Research Laboratory	96	347	20.9
New Brunswick Electric Power Commission	26	334	9.3
Others (government departments, industry, universities, etc.)	270	729	45.3
TOTAL	5 042	16 146	837.2

PART II

HYDROCARBON PROCESSING RESEARCH LABORATORY

PART II

HYDROCARBON PROCESSING RESEARCH LABORATORY

HIGHLIGHTS

In 1986/87 HPRL furthered the reputation of ERL as a centre of expertise for the primary and secondary upgrading of Canada's hydrocarbon resources. Research activities focussed on developing catalytic processes for the production of liquid fuels particularly technologies showing promise for commercial application in Canada. Primary conversion concentrated on developing catalysts for upgrading bitumen, heavy oil, coal, coal/oil mixtures, natural gas and their byproducts and residues to suitable feedstocks for refinery operations. Secondary upgrading studies involved the design and evaluation of catalysts for the production of specification transportation fuels from both conventional and advanced primary conversion processes. These activities were complemented by shared cost and collaborative research conducted in cooperation with industry. Also, fundamental studies carried out in concert with universities were expedited by the commissioning of several advanced facilities for hydrocarbon processing and catalyst characterization.

Several significant outputs were achieved in primary processing. Studies on conversion of asphaltenes identified the optimal catalyst pore size diameter for viscosity reduction of bitumen and heavy oil to meet pipeline specifications. A fluidized bed technique employing a microbalance reactor was developed for investigating the catalytic pyrolysis of refractory pitches to produce saleable liquids. Disposable bimetallic catalysts for the conversion of bitumen/heavy oil/coal mixtures were tested and found to perform better than conventional alumina supported catalysts for both feedstock conversion and heteroatom removal.

Secondary upgrading studies continued to maintain a high profile. A techno-economic feasibility study on a low severity process for the production of specification diesel fuel from synthetic crude middle distillate was initiated to determine near term commercial applications of the technology. Research in this area was expanded on the recommendation of the Minister's National Advisory Council to CANMET Subcommittee on Oil and Gas to include the production of specification jet fuel from synthetic crude middle distillate. The objective of this aspect of the program is to develop catalysts which will selectively convert fuel components which could pose problems with respect to soot formation in jet turbines. Progress on these studies was substantially augmented by the commissioning of an automated micro-reactor which allows hydroprocessing studies on small quantities of liquids for extensive times on stream and the development of advanced surface spectroscopic and microscopic capabilities which permit in situ catalyst testing and characterization.

During 1986/87 ERL activities with respect to research on the conversion of natural gas to liquid fuels were significantly extended through the successful negotiation of participation in cofunded research agreements sponsored by the Gas Research Institute of Chicago and the

Stanford Research Institute. These initiatives which substantially leverage ERL's program provide access to studies being conducted by the international research community on the direct and indirect conversion of natural gas.

World wide consideration is being given to gasification processes as candidates for the clean use of coal. ERL research in this area is aimed at developing technologies which will accommodate low-grade and non-reactive fuels and reduce emissions of deleterious species including acid rain precursors and particulates. Progress towards accomplishing these objectives was highlighted by completion of the detailed design of a bench scale entrained bed gasifier and the testing of several low cost sorbents from the metallurgical and aluminum industries for the removal of acidic species from hot gas products.

The 1986/87 budget allocated to support the in house and contract activities was:

	$K
Salaries	1665
Capital	890
Operating	650
Contracts	2300

The staff prepared 41 research reports, published 41 research papers and made 49 presentations.

CATALYTIC HYDROPROCESSING SECTION

SUPPORT FOR CANMET DEMONSTRATION PLANT

Modified Additives and Improved Additive Preparation Processes

Support for the demonstration plant was provided in the form of assignments to the additive production site of the National Coal Company Research Centre in Bristol, Virgina and to the Montreal refinery. Four confidential reports were completed describing in-house experimental work carried out as part of the program.

PITCH CONVERSION

Catalytic Pyrolysis of Pitch

Experiments were conducted on the catalytic conversion of +525°C pitch into distillable hydrocarbon products. A fluidized bed technique wa developed to contact the pitch with the catalyst. A microbalance reactor was used to measure the quantity of distillable products and the amount of coke remaining on the catalyst. The amount of conversion was found to increase with increasing catalyst/oil ratio.

CONTRACTS

1. "Development and evaluation of catalysts for hydrogenation of raw Cold Lake pitch"

Flash hydropyrolysis experiments were performed using Cold Lake +525°C pitch as feedstock. Gas, liquid, and coke yields were measured as a function of hydrogen pressure, catalyst type, temperature and heating rate.

2. "An integrated retorting combustion system using fluidized bed technology"

3. "An integrated combustion system using fixed bed technology"

ASPHALTENE CONVERSION FOR VISCOSITY REDUCTION OF HEAVY OILS AND BITUMENS

Development of Catalysts for Low Conversion Upgrading

Development and testing of catalysts continued for converting asphaltenes in heavy feeds such as Athabasca bitumen to smaller molecular fragments to reduce the product viscosity enough for direct pipelining. Because of the presence of macromolecular asphaltenic species in these feeds often the catalyst must contain large pores for efficient conversion reactions.

Catalyst preparation involved treating alumina with strong solutions of nitric acid followed by low temperature drying, and calcining in air. An intermediate step which involved mixing the partially dried material with a polymeric binder and subsequently forming 1/16 or 1/8 in. cylindrical extrudates can be included when desired. The alumina supports had pore diameters from about 3 to 10 000 nm. The variables that contribute to a specific pore size distribution within this range included molarity of the acid solution, amount of alumina in the mixture and drying temperature. The alumina supports were impregnated with active metals by either pore volume impregnation or immersion in an aqueous solution containing the active metal for a fixed period followed by drying and calcining. The impregnation of active metals decreased the total surface area somewhat but did not affect the pore size distribution appreciably.

Viscosity changes in the hydrocracked product and relative activities for asphaltene conversion and HDS were found to correlate with pore diameters in the 3-200 nm range. Catalysts having pore diameters between 13 and 20 nm showed higher activities than those between 3 and 7 nm. The viscosity of the hydrocracked product was the lowest between 13 and 17 nm.

The rate at which large asphaltene molecules react is influenced by that at which they diffuse through the catalyst pore structure. A relationship describing the effective diffusivity of large carbonaceous molecules as a function of catalyst pore size was developed.

CONTRACTS

1. "Experimental evaluation of catalyst deactivation caused by asphaltene adsorption"

The objective was to assess the extent of loss of catalytic activities caused by the asphaltene species present in heavy feeds such as oil sands bitumen. The results of this study will provide a database for designing catalysts which retain their activities over longer periods when used for upgrading bitumen to transportation and other fuels.

2. "Catalytic hydrocracking of heavy oils in a layered fixed bed"

This contract is scheduled for completion in 1987 and will provide experimental evaluation of a new approach to primary upgrading.

3. "Industrial applications of microwave technology to catalytic processes"

This project is scheduled for completion in 1987 and will provide fundamental information on microwave enhancement of catalytic hydrogenation and hydrodesulphurization.

DISPOSABLE CATALYSTS FOR HYDROPROCESSING BITUMEN WITH COAL

A series of bimetallic catalysts supported on hydrous titanates was prepared by ion exchange with aqueous solutions of transition metals. These catalysts were tested in a semi-continuous reactor system for the coprocessing of coal and residual oil of petroleum origin. The data generated from product characterization indicated that oil yield, coal conversion and heteroatom removal were improved with these novel catalysts compared with those supported on alumina.

CONTRACTS

1. "Characterization of tin catalysts by Mossbauer spectroscopy"

Information on the oxidation state of tin active sites of coprocessing catalysts was obtained by Mossbauer spectroscopy. These catalysts were prepared and tested in-house.

2. "Low-temperature Mossbauer spectroscopy of tin catalysts"

Additional CANMET-prepared tin catalysts will be characterized by Mossbauer spectroscopy and scanning electron microscopy.

HYDROFINISHING OF SYNCRUDE MIDDLE DISTILLATES FOR DIESEL FUEL PRODUCTION

The objective is to develop a low severity process for refining middle distillates from synthetic crudes for the production of diesel

fuels. The work involves the fabrication of highly active hydrogenation catalysts which have increased resistance to deactivation by sulphur. Large pore catalysts of high metal loadings were fabricated using deposition-precipitation methods and also by using additives to generate open-pore structures. Catalysts were characterized by scanning electron microscopy, electron microprobe analysis and X-ray diffraction. Polished catalyst sections were prepared so that the internal pore structure could be examined. The distribution of pores was determined accurately using mercury porosimetry which also allowed an estimate of the average pore diameter and total pore area. These aspects of catalyst structure are important since hydrogenation reactions occur in the liquid phase and may be diffusion controlled. The chemical nature of the active phases in these catalysts after drying and calcining was established using X-ray diffraction and electron microprobe analysis.

An automated microreactor system was commissioned through rigorous testing of reactor modules and computer software. The system was operated continuously by computer control for periods in excess of 500 h and a standard procedure for screening catalysts was developed. Catalyst deactivation studies are in progress and involve running reactions for extended periods of time on stream to establish catalyst life and tolerance to sulphur poisons in distillate feedstocks.

CONTRACTS

1. "Dearomatization of synthetic crude"

This contract is scheduled for completion in 1987 and will provide fundamental information on the application of phase-transfer catalysis to refining of syncrude distillates.

2. "Compositional analysis of hydrotreated middle distillates from synthetic crudes by mass spectrometry"

3. "Analysis of synthetic crude middle distillate fractions by C-13 NMR"

CONVERSION OF NAPHTHENES IN JET FUELS FROM OIL SANDS

The objective is to generate higher quality hydrocarbons with improved molecular structures in synthetic jet fuels. Current industrial processes generate kerosene from oil sands which are highly napthenic and recent research indicates that saturated polycylic structures may be sources of soot in combustion processes. Dehydrogenation reactions may revert polycyclic naphthenes to their hydroaromatic forms andby a process of further hydrogen loss eventually form aromatics and particulates.

Preliminary experimental work was done to establish leads in developing catalysts with selectivity for ring-opening reactions. These reactions involve selective activation of carbon-carbon bonds in cycloparaffin structures such that products from ring scission are not cracked further to lower molecular weight hydrocarbons outside of the kerosene boiling range. A paper will be presented at the American Chemical Society, Denver Petroleum Division Symposium "Structure of Future Jet Fuels" in April.

CONTRACTS

1. "Shock tube combustion of aromatic and naphthenic hydrocarbons in jet fuels derived from Canadian tar sands"

The objective is to assess quantitatively the extent of dehydrogenation reactions that might occur in the pre- and post-combustion zones of jet engines using hydrogenated syncrude distillates as jet fuels.

2. "Development of metal cluster catalysts for conversion of middle distillate fractions in synthetic fuels"

NOVEL CONCEPTS FOR UPGRADING SYNTHETIC CRUDES

Several molybdenum-nickel oxide catalysts were prepared by impregnation of various supports. Techniques for catalyst evaluation by the adsorption of probe molecules and by reaction with model compounds were developed and reported. Synthetic distillate hydroprocessing studies continued and were reported. A project involving the application of fractal geometry to characterize porous solids resulted in four publications. New concepts involving polymer supports and metal cluster hydrotreating catalysts were explored.

A research program, involving a 70-day tenure by an HPRL scientist at the National Chemical Laboratory for Industry (Japan), was undertaken to investigate the utilization of zeolites and titania supports in catalysts for hydrotreating of coal-derived middle distillates. A report was written and delivered to the Science and Technology Agency of the Government of Japan. Also, the visiting HPRL scientist was the recipient of the Japanese Government Research Award for Foreign Specialists.

CONTRACTS

1. "Software development for automated R&D reactor system in distillate upgrading"

Software development and testing was completed. However, new modifications continue to be implemented. A description of the control system was presented at the 36th Canadian Chemical Engineering Conference, Sarnia.

2. "Role of catalysts in heteroatom removal during hydroprocessing of model compounds"

This contract was completed and resulted in a journal submission on the H_2S uptake by Mo/Al_2O_3 catalysts. A literature review is being prepared for publication.

3. "Preparation and catalyst activity of supported group V B and VI B metal clusters"

The potential of supported clusters of metals of group V B and VI B was assessed for the catalytic conversion of synthetic crudes. Catalysts were tested using model compounds for cracking potential (cumene) and for hydrodesulphurization (thiophene). Evaluation of the most active catalysts will continue using a synthetic gas oil.

4. "Upgrading of synthetic crude distillates with commercial catalysts"

The objective is to perform hydrotreating experiments on synthetic crude distillates and evaluate the applicability of conventional hydrotreating technology to the refining of new generation feedstocks such as those derived from heavy oils and enhanced oil recovery crudes.

5. "Preparation of new metal catalysts supported on ZSM-5 for the deoxygenation of organic compounds"

New procedures for loading metals on ZSM-5 zeolites were devised and a better dispersion of the metal active sites was achieved. A high conversion of methanol to hydrocarbons was obtained and extensive characterization of these catalysts by electron spectroscopy chemical analysis (ESCA) and infrared spectroscopy was carried out.

CATALYSIS RESEARCH SECTION

HYDROFINISHING OF SYNCRUDE MIDDLE DISTILLATES FOR DIESEL FUEL PRODUCTION

Novel Thin Film HDS Catalysts (Phase I)

Work continued in-house and by contract on developing thin film Co-Mo-Al oxides (50 nm) supported on Al metal for use as hydrodesulphurization (HDS) catalysts. The HDS activity of the thin films greatly exceeds commercial catalysts per square metre of surface area. Design of a novel micro-activity testing facility was completed. Completion of the construction phase is expected in 1987.

CONTRACTS

1. "Hydroprocessing of aromatics using thin film Co, Mo-alumina catalyst surfaces"

Thin film Co-Mo-Al oxide catalysts were tested for HDS activity using advanced surface characterization techniques. The design, construction and testing of the catalyst mini-reactor unit and the catalyst high vacuum transfer unit were completed. Invention disclosure reports and patent applications have been filed.

2. "Determination of Co-Mo-Al thin film catalyst activity for hydroprocessing of synthetically derived distillates"

Detailed testing and characterization of specific thin film catalyst compositions were initiated. Design changes and upgrading of the vacuum transfer device and mini-reactor unit will permit more versatile operation and improved performance. A novel feedstock delivery system is planned to permit closed loop recirculation testing.

CONVERSION OF NAPHTHENES IN JET FUELS FROM OIL SANDS

Catalytic Processes for Ring-Opening of Naphthenes

Work continued on formulating large pore Ni-Al-Si and Ni-silica catalysts for use in hydrogenation of middle distillates. Surface spectroscopic measurements of precipitated Ni-Al-Si catalysts prior to and following hydrogen reduction indicated the presence of a $NiO/Ni(OH)_2$ type easily reducible, a Ni/silica type more difficult to reduce and a Ni/alumina type not reducible. Presentations at national and international conferences are planned for 1987.

PITCH CONVERSION AND FLUID CATALYTIC CRACKING (FCC)

Assessment of Synthetic Gas Oils for FCC

Work continued on the use of a microactivity (MAT) test unit to experimentally evaluate and predict the performance of synthetic crude gas oils versus conventional gas oils for FCC operations in Canadian refineries.

CONTRACTS

1. "The degradation study of a metals-tolerant catalyst by molecular probes"

The objective was to develop an understanding of the catalytic cracking process using a modern metals-tolerant catalyst. Microactivity tests were conducted on pure components and on blends commonly found in heavy oils and synthetic crudes. Both product and molecular yields were determined for each MAT test.

2. "Fluid catalytic cracking of non-conventional gas oils by an octane-enhancing catalyst and a metals-tolerant catalyst"

Recent FCC operation is emphasized on the production of high octane gasoline to cope with the lead phase-down problem. This contract was designed to study the cracking characteristics of synthetic and conventional gas oils over both octane-enhancing and metals-resistant catalysts using a MAT unit. Lloydminster heavy oil, Cold Lake heavy oil, Suncor oil sand bitumen and a conventional Western Canadian crude were chosen for this study.

NOVEL AND IMPROVED PROCESSES FOR THE CONVERSION OF NATURAL GAS TO CETANE OR OCTANE BOOSTERS

Technologies for natural gas conversion are in their infancy. Research efforts worldwide have concentrated on the development of indirect routes involving first the production of synthesis gas through steam reforming followed by hydrocarbon synthesis loops such as Fischer-Tropsch at SASOL, methanol and methanol-to-gasoline (MTG) in New Zealand. The objective of this project is to evaluate the suitability of direct routes for Canada.

In the initial stages the program will monitor and evaluate the rapid technological changes in this area. A review of existing and potential routes for the conversion of natural gas to liquid fuels is in progress. The information obtained will be used to develop a strategy for the research program. This review will be complemented by an in-house program for the screening of novel approaches to converting natural gas to liquid fuels. Contracts will also be used to explore the feasibility of emerging technologies. Three contracts are already in place to examine the feasibility of converting natural gas in a single step.

Work continued on developing bi-metallic novel thin film catalysts (Ni/Cu, Fe/Cu) for converting natural gas to premium quality fuels (boosters). The design of a novel micro-activity testing and surface spectroscopic characterization facility was completed. Completion of the construction phase is expected in 1987.

CONTRACTS

1. "Optimization of the hollow cathode arc process for the conversion of natural gas"

The objective is to improve the hollow cathode arc process by devising a way to control the polymerization reaction in order to obtain a liquid. Work focusses on measuring the effect of process variables on polymerization and on designing a new electrode.

2. "Opportunities in the catalytic conversion of natural gas to liquid fuels"

The objectives are to evaluate and compare existing technologies and assess the status of R&D in this area. Business opportunities and market potential of one-step technologies will be evaluated. A survey of research on methane activation is also planned.

3. "Direct partial oxidation of methane to methanol over designed heteropoly catalysts"

The objective was to prepare a series of heteropoly compounds (acids and their salts) having high molecular weight anions and to test their activity and selectivity at converting methane to methanol. Results showed total methane conversion and methanol selectivity was low. Additional fundamental work is required.

4. "Conversion of methane over selected solid catalysts"

The objective was to screen a series of solid catalysts for converting a methane/propylene feed to C_5 and higher hydrocarbons. A microreactor system capable of operating at 700°C and 10 atm was assembled for these studies. The catalysts included various supported nickel catalysts activated by CH_4, mixtures of amorphous oxide catalysts and Ni-Ga-loaded zeolites. Catalysts were prepared and work initiated on the activation of the nickel supported catalysts in the presence of CH_4.

5. "Natural gas conversion to liquid fuels over superacids"

The objective was to screen a series of solid superacids for converting a methane/acetylene feed to C_5 and higher hydrocarbons. A bench-scale tubular teflon-coated reactor system capable of operating at 100°C and 10 atm was constructed. An exhaustive literature survey was carried out to ascertain the state of the art in processing and to finalize the reaction conditions for testing the catalysts. A large series of catalysts was prepared and characterized chemically.

6. "Investigation of process conditions for the synthesis of liquid distillates from light olefins and methanol"

Two areas were selected for the assessment of ethers for gasoline octane enhancement. The first concerns their processability which depends upon their carbon number. The second involves using this information with gasoline octane blending results in a linear programming study to determine the economic viability of the ethers with various refinery configurations. The results will serve to determine the economic feasibility of ether blending in Canadian refineries.

7. "The direct conversion of methane to methanol by a high pressure partial oxidation reaction"

Considerable progress has been made on the formation of methanol by the direct non-catalytic oxidation of methane in a high pressure plug-flow reaction system. The reaction was studied up to 125 atm and up to 550°C in a glass lined tubular reactor. The products included CO, CO_2, H_2O, CH_3OH with traces of C_2H_6, CH_3OCH_3 and CH_2O. The comparable natural gas reaction occurred at about 100°C lower than that for CH_4. Methanol selectivities of 70 to 80% were achieved at methane conversion of 8 to 10% under suitable reaction conditions.

DESIGN AND EVALUATION OF CATALYSTS FOR THE CONVERSION OF NATURAL GAS TO DIESEL FUEL VIA SYNTHESIS GAS

Catalyst Development for the Selective Production of Diesel Fuel

The objective is to design technologies that can be integrated into existing plants. Most indirect routes are based on conventional fixed bed technology and may be quite suitable for integration into existing facilities. It is well known that Fischer-Tropsch gives very high cetane diesel. The blending of diesel fuel from Fischer-Tropsch low cetane middle

distillate may be a viable upgrading strategy. Furthermore, it may be possible to integrate Fischer-Tropsch technologies with residue gasification technologies to convert unwanted residues to liquid fuel.

This project focusses on developing synthesis catalysts with increased selectivity for producing high cetane diesel fuel. These studies are carried out both in-house and under contract. In-house preparation of catalysts has been initiated. An iron-based catalyst will be tested to establish a reference case for FT conversion. The next phase of research will concentrate on the design and evaluation of shape-selective catalysts. To complement the testing facilities a system for the chemical characterization of catalysts based on a combination of temperature programmed desorption/reaction, Fourier transform infrared spectroscopy and mass spectrometry has been commissioned. This system will be very valuable for examining catalysts under realistic operating conditions. This information will be used to determine the reaction mechanism and to design more efficient catalysts.

CONTRACTS

1. "Carbon molecular sieve based synthesis for diesel fuel production"

This project involves preparing and testing a series of novel shape-selective molecular seive catalysts. The strategy is to use various synthesis routes as a means of controlling the pore size and the activity of these catalysts. The objective is to maximize the selectivity for diesel.

2. "The direct conversion of synthesis gas to diesel over a modified zeolite catalyst"

The objective is to test a series of novel promoted zeolite catalysts for the conversion of syngas to diesel fuel. Preliminary results have shown that these catalysts could produce diesel up to 30% of the liquid yield. Research now focuses on increasing the liquid yield and decreasing the formation of carbon dioxide.

3. "The direct conversion of syngas to diesel over asbestos-based catalysts"

The objective is to synthesize and test a series of asbestos-based catalysts for the conversion of syngas to diesel fuel.

4. "Construction of a system for in-situ chemical characterization of catalysts"

The objective is to build a unique system design at ERL.

5. "Design and construction of heated liquid sample transport system"

The objective is to develop a special reactor-gas chromatograph interface suitable for high temperature high pressure sampling.

CONVERSION OF NATURAL GAS TO HIGH OCTANE FUELS/OCTANE BOOSTERS VIA ACETYLENE

Design and Evaluation of Catalysts for the Production of BTX from Acetylene

A bench-scale continuous-flow tubular reactor was used to examine the potential of a series of fluorinated alumina catalysts in synthesizing benzene, toluene, and xylene (BTX) from acetylene. Although patent literature indicates that fluorination has been used successfully to enhance the polymerization of highly unsaturated molecules, e.g., conjugated dienes, no improvement was observed with acetylene. Catalyst deactivation was severe. This deactivation was explored in more detail in experiments carried out on a microbalance. Total coke deposition decreased with fluorination. However, results showed that the species believed to be causing the deactivation increased with higher catalyst fluoride content.

SEPARATION AND CHARACTERIZATION SECTION

CHARACTERIZATION OF SYNTHETIC CRUDE, GASOLINE, DISTILLATE AND ASPHALT

Studies continued on the asphaltic properties of processing residues. However, instead of using the +524°C heavy fraction synthetic crudes are being distilled to desired penetration and/or viscosity values. It is intended to establish an inventory of the asphaltic properties of residuals from all available synthetic crudes.

A study was completed on new mass sensitive detectors for liquid chromatography. Considerable progress has been made on novel packings for improved size exclusion chromatography for determining molecular weight distribution. Significant progress was made on the characterization of nitrogen and oxygen compounds in synthetic crudes.

CONTRACTS

1. "A techno-economic evaluation of conventional, synthetic and oxygenated gasoline blending components"

The objective is to determine optimum blends for future gasolines. These gasolines contain both synthetic and conventional crude components that have been processed at different severities as well as appropriate oxygenates to meet future specifications including lead phase-down.

2. "Quality and applications of asphalt derived from upgraded heavy crude"

The residues from two different bitumen upgrading processes were investigated for producing road and roofing quality blends.

3. "Detailed study of the influence of experimental conditions on retention time in size exclusion chromatography of bitumen/heavy oils/asphaltenes"

The objective is to determine operating conditions that will generate a separation as close as possible to true size separation in order to ensure adequate determination of molecular weight distribution.

SEPARATION OF SYNTHETIC CRUDE FRACTION

Work continued on the separation of methanol from etherification products by reverse osmosis using various membranes. Membranes can be specified that selectively permeate or reject methanol from the etherification products as desired.

Studies on the sorption of heteroatom compounds in synthetic crudes continued in order to develop methods for their removal. Work continued on zeolites, modified zeolites and other sorbents.

Considerable progress was made in establishing modified facilities for studying membrane separation of synthetic crude fractions. Also, new facilities are being established for sorption studies at higher temperatures and on a larger scale.

CONTRACTS

1. "Reverse osmosis separation of model compounds in heptane and toluene solutions"

Studies on the reverse osmosis of pure compounds have been made in order to interpret results from synthetic crude separations.

2. "A study into the separation of nitrogenous materials from naphtna fractions"

Sorption investigations at different temperatures using various sorbents were made at conditions simulating industrial operations.

3. "Separation of sulphurous components in synthetic crude fractions"

Sorption studies on sulphur compounds in synthetic crudes are being carried out.

4. "Reverse osmosis separation of methanol from ethers and unreacted olefins"

The objective is to develop technologies for separation of methanol from actual etherification products as opposed to simulated products used for in-house work.

5. "Adsorption of nitrogen compounds"

A study is underway to investigate adsorption of synthetic crude nitrogen compounds on different zeolites at various conditions.

CHARACTERIZATION AND SEPARATION OF PRODUCTS FROM BITUMEN/HEAVY OIL IN SITU RECOVERY OPERATIONS

Several breakthroughs were achieved in the ultrafiltration of oily effluents using polymeric membranes to produce water for steam generation. Commercial applications appear promising. The results of a study on a rotating dynamic membrane ultrafiltration process were not encouraging. The study was discontinued.

A report was prepared on the characterization of corresponding samples of primary and fireflooded Saskatchewan heavy oil (Eyehill).This work is part of a Canada-US tar sands project. Samples were obtained from the Marguerite Lake operations that include cores, steamflooded and fireflooded samples.

The surfactants from a bitumen in water emulsion from a steam flooding recovery operation were separated by ultrafiltration and characterized. They were found to be similar to humic and fulvic acids.

CONTRACTS

1. "Analytical methods development and characterization requirements for projects on resource characterization"

This work supports the Canada-US cooperative project for studying the effect of recovery methods on heavy oil projects. It involves the Eyehill primary and fireflooded heavy oil.

2. "Extraction and characterization of crude oils from primary and enhanced recovery operation"

3. "Separation and characterization of surfactants present in emulsions in enhanced recovery process"

Surfactants from various diverse enhanced oil recovery operations are being studied.

4. "Development of a process for treating oil-water-mineral emulsions from in situ operations"

Coagulation/flocculation of multivalent chemical agents have been studied.

5. "Membrane processing of oil field produced water for enhanced oil recovery (EOR) steam generation"

This study involves polymeric membrane ultrafiltration of oily effluents to produce steam generator quality water.

GASIFICATION SECTION

HOT GAS CLEAN-UP OF GASIFICATION PRODUCTS

The objective is to develop a new adsorbent for removal of acidic compounds from gasification products at high temperatures. This would significantly improve both the thermal efficiency and environmental attractiveness of the combined cycle power generation process. Several low cost solids disposed from metallurgical and aluminum industries have been successfully tested. Experimental results from in-house research are presented in technical reports.

CONTRACTS

1. "Hot gas clean-up of gasification products"

GASIFICATION OF NON-REACTIVE FEEDSTOCKS

An entrained bed gasification system is being constructed to characterize non-reactive feedstocks under conditions of the most advanced gasification processes. Thus entrained bed gasification reactors are part of the integrated gasification combined cycle commercial process producing electricity from coal at very low acidic emissions. As part of this project the evaluation of gasification reactivities of Canadian coals continued.

CONTRACTS

1. "Gasification of anthracite in fluidized bed"

2. "Preparation of oil sand coke-water slurry for Texaco gasifier"

3. "Preparation of pitch-water slurry"

LIQUID PRODUCTION POTENTIAL OF CANADIAN OIL SHALES

An awareness of the R&D activities in Canada and other parts of the world was maintained and information files were updated. Several samples of Eastern Canadian oil shales were evaluated with respect to their liquid production potential.

CONTRACTS

1. "Process evaluation of an integrated oil shale retorting-combustion system"

2. "Co-pyrolysis of New Brunswick oil shales with Minto coal"

3. "Beneficiation of Nova Scotia oil shales"

ANALYSIS AND STANDARDIZATION SECTION

In 1986/87 analytical support was provided to research and industrial clients by carrying out 30 000 determinations on 2000 solid and liquid fuels and related materials. These analytical services were complemented by continued contributions to national and international standards organizations and by coordination of the CANMET Service Program for the Evaluation of Characterization Standards (CANSPECS) round robin coal sample exchange program.

Analytical support activities concentrated on the determination of the physical and chemical properties of feedstocks, products and residues from research projects related to the production, utilization and conversion of hydrocrbon fuels as well as coals. The complex relationships which exist between these physical and chemical parameters were identified and verified with a view to assessing the progress of novel technologies or evaluating the market potential of Canadian coals.

Within Canada, public and private sector organizations employ both American Society for testing and Materials (ASTM) and International Standards Organizations (ISO) procedures in order to evaluate coal quality.

These standards are continually reviewed and new procedures are developed to respond to the need to assess wider ranges of coal quality or to evaluate properties which have an impact on novel technological applications.

To ensure that new and revised procedures implemented by ASTM and ISO are compatible with Canadian interests the section continued to contribute to the deliberations of these standards groups in an advisory and consultative role.

As a complement to participating in the activities of these organizations the section continued to coordinate the CANSPECS. This program distributes commercially produced Canadian coals to 50 laboratories within Canada and abroad for analysis of specified parameters of coal quality. The exprimental data obtained are employed for the assessment of the analytical acceptability of proposed standards and the evaluation of laboratory performance with respect to existing standards.

PART III

COMBUSTION AND CARBONIZATION RESEARCH LABORATORY

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HIGHLIGHTS

The combustion and carbonization research at CANMET continued to serve as a focal point for projects being undertaken by industry, universities and other federal agencies. Increased efforts were made to ensure that in-house and contract research projects were integrated with related work being done by other organizations and that an orderly transfer of technology would occur by providing substantive support for demonstration and commercialization activities by others. In addition, the scope of participation in foreign R,D and D programs was increased to maintain close ties with significant technology developments of interest to Canada.

Two major demonstrations, the Chatham circulating fluidized bed and the Charlottetown boiler conversion to coal/water fuel were funded by EMR's Coal Division with considerable technology input from CCRL staff. Both demonstrations involve leading-edge but unproved concepts which required on-site monitoring and analyzing of problem areas. Other demonstrations co-funded by CANMET include the low-NO_x/SO_x burner retrofit at CFB Gagetown, the sorbent injection trials at Boundary Dam Generating Station, the evaluation of coke from Algoma Steel's coke oven trials and a ground-source heat pump for commercial heating.

The in-house research resulted in a number of accomplishments:

- three coals from newly opened seams were characterized in the pilot-scale research boiler for combustion, deposition and emission properties;

- a feed system to burn pitch and raw bitumen in the bubbling fluidized bed pilot plant was designed, constructed and proved;

- the reactivities of iso-stability coke from Western Canadian and Appalachian coals were compared;

- a procedure for on-line refinery monitoring of the combustion characteristics of middle distillate fuels was developed.

Contract research with industry and universities is used extensively to address knowledge gaps, to develop outside specialized expertise and to encourage external co-funding of projects. Key areas involved studies of the physico-chemical qualities of oxidized coal surfaces; the commissioning of a pilot-scale combustor for elucidating NO_x/SO_x conversion in flames; the feasibility of using a low-pressure steam heat pump for use in the pulp and paper industry; and the burning of high-sulphur Syncrude coke with 90% sulphur capture.

CCRL's budget for 1986/87 was allocated as follows:

	$K
Salaries	2276
Capital	895
Operating	1002
Contracts	2145
TOTAL	6318

The staff prepared 35 research reports, published 42 research papers and made 72 presentations.

ENERGY CONSERVATION TECHNOLOGY

SPACE HEATING - OIL AND GAS

The objective is to reduce consumption of fuels for space and service water heating through improved combustion technology and the optimization of operational conditions while ensuring safe operating conditions and minimal impingement on the environment.

The major emphasis is on the evolution of technology and strategies to replace oil with natural gas as the primary space and water heating fuel. By developing retrofit devices and new designs of combustion systems to improve burner/furnace efficiency and reduce potential unsafe operating conditions with present systems and to encourage more energy efficient housing, efficiency improvements from 20% to 40% are possible. By using substitute and degraded liquid fuels additional oil may be available for transportation.

In-house R&D continues on new technologies for space and water heating with additional projects undertaken mainly by contract. Development of specific advanced technologies is also carried out by contract to industry. Seasonal performance experimental procedures are being developed and new designs are being produced. The results are transmitted to standards writing agencies, testing laboratories, manufacturers and government agencies through standards committees, published papers, seminars, associations, e.g., Canadian Standards Association, Canadian Gas Association, Canadian Wood Energy Institute, Ontario Petroleum Association and Canadian Home Builders Association and through close cooperation with individual manufacturers and utilities. Liaison is also maintained with US developments, particularly relating to environmental concerns and alternative technologies.

The retrofit condensing furnace, developed by CCRL and Clare Brothers, which can augment the efficiency of the existing gas furnace in the home by 20-30%, has now been placed on the market in both Canada and the US by Clare. Additional technical support is being given to Clare by CCRL to help illustrate that the unit is not only more efficient, but also considerably safer than existing unmodified gas furnaces. A number of American agencies are particularly interested in this equipment for potential retrofit on a large scale.

A second generation prototype of the plastic condensing furnace, using a polyethylene/polypropylene co-polymer, has been constructed using the new material with actual manufacturing-type bonding techniques. An optimized fan/motor control system has been undergoing long-term cyclic testing at CCRL. No serious problems have occurred.

Testing has been carried out on two gas-fired combined space and water heating systems, one condensing and one non-condensing. Both systems show promise for future applications in low energy housing where the water heating load begins to approach that for space heating.

A conventional gas furnace was retrofitted with an induced draft fan and an electronic ignition system. The technique showed potential energy savings of up to 15%, with improved venting performance, making the appliance more suitable for tighter or low draft housing. Complementary action was carried out by a contractor, preparatory to a potential large-scale field trial.

Condensing systems fired by both oil and gas have been examined. In particular, the presence of smoke and higher levels of acidity in the condensate, due to fuel sulphur, makes condensing somewhat more difficult for oil systems than for gas. An innovative system used a circulating water system which condenses and dilutes the flue gases using a direct water spray.

Technical support has also been given to a number of research and standards writing organizations concerned with the safe venting of combustion appliances and with new standards for chimneys and fireplaces, including guidelines for appropriate flue sizing.

Increased use of Canadian distillate fuel oils processed from synthetic crudes has raised concerns about possible deterioration in combustion performance. In cooperation with the oil industry a series of experiments has been carried out to examine the effect of fuel quality degradation on combustion characteristics such as burner ignition behaviour, emissions of incomplete combustion products, furnace temperatures, efficiencies and excess air levels in controlled laboratory experiments, simulating a real-life home environment. The test protocol requires a 1-h steady state run from cold start followed by five 10-min on, 10-min off cycles.

Fuels are analyzed for their paraffinic, olefinic, naphthenic and aromatic contents, as well as viscosity, density, carbon residue, elemental components, distillation range, etc. The experimental results show that whereas the combustion characteristics are influenced by interacting physical-chemical properties, fuel aromaticity and viscosity show a strong correlation with particulate and gaseous emissions.

Results indicate that fuel viscosity exhibits a strong influence on the production of incomplete combustion products. Aromaticity has a significant impact on combustion. Cold start emissions exhibit an exponential relation with aromatic components whereas emissions from warm start show a linear relationship.

Preliminary analysis suggests that the optimum limits of fuel properties are: viscosity 4 cSt at 40°C; aromaticity 45% or aromatic content 60%; and calculated cetane index 25, for residential oil furnaces equipped with flame retention head burners.

Potential exists for significant reductions in energy consumption by improving the efficiency of residential oil-fired heating systems. Clare Brothers have developed, under contract, a high efficiency, low-air-requirement oil furnace for northern applications. Potential fuel savings are greater than 20%, relative to a conventional furnace, without condensing.

Severe problems may occur with the venting of combustion appliances in both new and existing housing. In cooperation with Canada Mortgage and Housing Corporation, the operational characteristics of fossil fuel- and wood-fired appliances are examined in relation to the chimneys they feed. Both steady state and cycling characteristics are important. Changes in fuel, the use of mixed energy sources and improvements in efficiency have all affected the chimney environment. Modifications to the venting system, such as relining and repair, the use of double walled flue pipe, or modifications to the furnace/burner system, such as the retrofit induced draft fan system described previously, may improve the venting performance.

INDUSTRIAL ENERGY CONSERVATION

This program, previously called ENERSOLVE, is concerned with increasing the efficiency of utilization and reduction of consumption of fuel in industrial processes. Much of the present industrial equipment, particularly if more than 10 years old, may not be operating or even operable at maximum attainable fuel efficiency. Scope exists to technically upgrade most installations to attain greater fuel economy. The program is intended to support a limited number of specific studies on retrofit of combustion systems in a variety of industrial sectors and regions of Canada. By this means, a fully documented capability for energy conservation will be formulated by the performers, enabling them to subsequently and privately offer such services to industry in general, perhaps even with a guaranteed pay-back.

During the ENERSOLVE studies it was found that Canadian industry often uses rigid procedures developed for steam-raising boilers with specific fuels to determine performance without realizing the simplifications or complexities required for other industrial processes and for different fuels. It has become apparent that there is a significant lack of knowledge of the fundamentals of combustion system analysis and of the major potential benefits that may accrue from improvements to that system. It is important that the general principles, industrial results and the fact that there are now Canadian consultants who are developing the skills to provide such a service to industry should be made widely known.

Two potential industrial sites for a retrofit flue gas condensing system on a gas-fired unit have been evaluated under contract. One site is a meat packing plant in British Columbia, the other is a pulp and paper boiler in Ontario.

ENERGY SYSTEMS

After considerable advances in recent years, the energy efficiency of many individual technologies may be approaching practical limits. There remains, however, considerable improvements through the use of integrated energy systems. Cogeneration is an excellent example whereby the combined production of heat and power can achieve much higher levels of efficiency than if produced separately. Similarly, the creation of systems to recover and distribute "waste" heat or materials from which energy can be produced can yield significant overall gains in the efficiency of community energy use. District heating, heat pumps and energy storage are seen as major technologies that contribute to the successful application of energy systems technology.

Within CCRL, this work is primarily one of contract research, with all work closely controlled through interdepartmental and private sector committees. Coordinating committees ensure that there is no duplication of effort and that the work done is as of wide interest as possible and that the information may be transferred to industry for application as soon as possible.

In district heating the major challenge has been to improve the understanding of modern hot water technology in Canada, and to develop a better appreciation of the benefits of the technology to communities. This is being achieved and projects are underway in Eastern Canada; Public Works Canada and several universities are reconsidering district heating as a desirable means of providing space heating and/or cogeneration at their facilities.

The heat pump program has focused on the development of high temperature units for industrial application, the development or application of new working fluids for a variety of applications and the improved cost-effectiveness of efficient ground source technology. International Energy Agency participation has been of major benefit to this program. Canadian manufacturers and research organizations are heavily involved in all aspects of our program. One of the world's first vapour recompression steam generating heat pumps is under construction at the National Research Council, based on a design developed in this program. Follow-up applications with the pulp and paper industry are anticipated.

BIOMASS COMBUSTION

Residential Wood Combustion

Wood stoves have been shown to be an efficient and often cheap way to heat a house. However, significant amounts of incomplete combustion products can often be produced, resulting in a potential fire hazard if deposited in the chimney in the form of creosote, or in a severe air pollution problem, in areas of poor fumigation. CCRL efforts have been directed towards changing the design of these appliances in order to improve combustion performance and by generating techniques by which the performance can be effectively measured.

In addition to carrying out further work to finalize these standards, CCRL is now carrying out an experimental program to extend the standard to cover central heating appliances. Other efforts are primarily geared to develop techniques or strategies to improve the performance of existing appliances in the field.

Round robin testing of the proposed CSA standard for efficiency and emissions from wood stoves has been completed successfully, with a similar procedure also being adopted by ASTM in the USA. Work has been proceeding on techniques to improve the performance of existing appliances, and technical support is being given to a long term field study of appliance performance in homes in Vermont and New York State, sponsored by the Coalition of North East Governors.

A similar study is being carried out in Whitehorse, Yukon Territory, to determine the potential of new and retrofit technology to improve efficiency and reduce emissions from stoves, in an area that has one of the most severe woodsmoke pollution problems in North America. Support for this program has also been carried out in the laboratory, concentrating on the potential for developing retrofit catalyst technology and operational guidelines to improve the performance of existing stoves.

Over the year, a number of advanced design wood stoves have also been tested in the laboratory. There has also been considerable test procedure development and refinement, both for CSA and for ASTM.

Central wood furnaces, because of their cyclic on-off "stew" operation in response to thermostat control, have the potential to be major pollution emitters and cresosote generators while suffering efficiency penalties. Determination of their seasonal performance requires a combination of the cyclic procedure developed for gas furnaces with the fuel composition change developed for wood stoves. Techniques are being developed to enable furnace manufacturers to improve the design and operation of their appliances, and to regulators to determine feasible techniques to control the emissions from such units. Combining work in the laboratory and contract work with the Centre de recherche industrielle de Québec, techniques are being developed to measure the cyclic performance of central wood burning furnaces and boilers, and to give design changes to these extremely poor performing appliances.

Papers have been presented on the wood furnace work, on techniques to improve performance of existing stoves, on the interaction of wood burning fireplaces and stoves with other air demands in tight housing and on the requirements of chimneys to safely serve these appliances.

Industrial Wood Combustion

Since 1980 CANMET has provided substantial scientific support to federal and private sector programs related to the combustion of biomass in industrial boilers and processes. This support has included the evaluation of proposals, advice on new initiatives, the formulation of project tasks and the management of contracts.

Two research contracts valued at $1550 K over five years were completed in 1986, under a program jointly funded by ENFOR and the Bioenergy Development Program to measure the combustion, steam production and emission characteristics of four different industrial wood-fired boilers. These measurements, which are reported in a 14-volume set, have been applied by the participating plants to reduce steam costs significantly and by the industry in general to optimize specifications for new equipment. Plans for 1987/88 call for a detailed evaluation of the four sites under contract.

A pilot-scale industrial wood burning system, rated at 250 kW, is now being installed at CCRL to develop combustion performance guidelines for commercial and industrial wood chip-fired and other processed wood-fired units.

COAL AND COKE CONSTITUTION

The behaviour of coals in the presence of CO and H_2O (water-gas shift reaction) has been thoroughly investigated. For naturally weathered coals, it has been demonstrated that enhanced reactivity in combustion, carbonization and liquefaction can be achieved by the water-gas shift process. This process has also proven amenable to upgrading low-rank non-coking coals, i.e., subbituminous coal and lignite for blending with coking coal to produce metallurgical quality coke. Sulphur reduction in fossil fuels has been addressed and preliminary results indicate that both organic and inorganic sulphur levels can be reduced in bituminous coals and even in relatively unreactive bitumen cokes. Work continues in this important area.

Weathering or natural oxidation reduces the coking tendency of coal and can make it difficult to burn. Consequently, work on the characterization of oxidized coals is continuing. In addition to using techniques such as Fourier transform infrared (FTIR) and ^{13}C nuclear magnetic resonance (NMR) to characterize coals the use of thermogravimetric analysis (TGA) to detect coal weathering was investigated. Detailed investigations on Canadian coals ranging from low-volatile bituminous to lignite reveal that TGA, under certain well defined experimental conditions, can be an excellent tool for characterizing caol oxidation. Work is continuing in this investigation.

The use of FTIR to study of weathered coals made significant advances based on our observation that it is possible to transform surface peroxides (ubiguitous constituents of coals) to carbonyl groups by both thermal- and base-promoted chemical reactions. These carbonyls can be measured quantitatively by FTIR using photo-acoustic detection. For oxidized coals, quantitative correlations between the level of thermally generated carbonyl groups and plasticity have been observed.

An extensive program to characterize the elemental distribution (both organic and inorganic) on coal surfaces using secondary ion mass spectroscopy (SIMS) is in progress. This technique enables a microscopic

portion of a coal surface to be visualized in terms of a suite of "ion images". This is of particular interest for materials which are highly heterogeneous such as coals. Valuable information both of a fundamental and practical nature is obtained by this technique.

In-house studies on porosity and surface area of coals indicate variations in these properties resulting from weathering which impacts unfavourably on combustion reactivity. These preliminary results would explain the wide variation in combustion performance observed on coals of similar rank. The concept of 'blocked' and 'open' porosity revealed by this study is applicable to a wide range of other processes, including coal conversion and gasification.

The study of coke formation in various fractions of bitumen in the presence of hydrogen has been completed. Quantitative data on the kinetics of coke formation show that the asphaltene fraction has the greatest tendency to produce coke during processing. These results, published in FUEL, are directly applicable to the CANMET hydrocracking process and are of fundamental interest as well.

To increase our knowledge of bitumen aging or weathering and its effect on processing various samples of fresh and laboratory oxidized bitumens were prepared and separated into maltene and asphaltene fractions. These fractions were examined by FTIR, ^{13}C nmr and chemical analysis and their tendency to produce coke under thermolysis conditions is being investigated in detail. The cokes will be examined by optical microscopy. This work is directly related to bitumen storage, handling and subsequent processing and may, as well, yield fundamental information on the mechanism of weathering of different bitumen fractions.

EMERGING ENERGY UTILIZATION SYSTEMS

Fluidized bed combustion, which is the main effort of this section, is recognized as a rapidly-maturing technology with several potential applications in Canada's unique energy situation. A primary application is the generation of electricity and process steam from high-sulphur coal. Additional applications include co-firing of coal and wood waste in the forest products industry, utilization of coal washery rejects, incineration of various organic wastes, and combustion of liquid or solid residues from oil sands/heavy oil upgraders. Federal support is necessary to ensure that the technology addresses each of these diverse requirements in an acceptable time frame.

Major objectives of the CCRL program are:

- to demonstrate the reliable performance and environmental benefits of FBC boilers in industrial and utility settings;

- to aid designers of FBC equipment by developing a databank on the combustion performance of a range of fuels, primarily Canadian coals and oil sands/heavy oil upgrading residues, and by developing a databank on the performance of various Canadian limestones as sulphur sorbents;

- to develop a databank on the concentration of trace elements, particularly metals, in selected fuels, and their fate when fired in FBC systems;

- to support other agencies in the development of FBC technologies by means of co-sponsored site-specific research, techno-economic studies, and demonstrations.

IN-HOUSE R&D ON FLUIDIZED BED COMBUSTION

Pilot-Scale Program

CCRL Mark II bubbling bed FBC pilot plant

The CCRL Mark II fluidized bed combustor is a versatile pilot-scale research facility which was installed at ERL in 1980. Important features are a combustor cross-section of 380 mm x 400 mm, variable in-bed feed, separate weigh feeders for fuel and sulphur sorbent, and provision for reinjection of fly ash from a multicyclone dust collector. Since its commissioning, the Mark II facility has been operated using a variety of coals and other fuels to develop a bank of combustion performance data which will ultimately be required by designers of full-scale systems. Much of the pilot-scale work has been in direct support of the CFB Summerside demonstration which is described later.

In the past year, pilot-scale trials were carried out on Brogan coal from Cape Breton, N.S., using Havelock, N.B. limestone as the sulphur sorbent. This work supplemented data obtained from the CFB Summerside demonstration, particularly with respect to the effects of limestone size consist on sulphur capture. Results were reported at the Joint ASME/IEEE Power Generation Conference held in Portland, Oregon in October 1986.

The main effort of the year was directed to exploring the combustion of heavy liquids, such as pitch residues from heavy oil upgrading. With residual oil as fuel, it was established that in-bed injection is required to avoid excessive freeboard combustion. Through trial and error, a water-cooled injector employing compressed air to disperse the fuel into the bed was developed. Baseline combustion performance data were obtained using residual oil and combustion trials using Athabasca bitumen were carried out. A similar program using CANMET pitch from the Petro Canada demonstration plant in Montreal was begun.

CCRL circulating FBC pilot plant

A second generation fluidized bed concept, known as circulating FBC, has shown advantages over bubbling-bed FBC in terms of more efficient

sulphur capture and increased ability to cope with unreactive fuels. Since it appears likely that circulating FBC will be employed in most large-scale FBC applications in Canada, it was decided in 1982 to equip CCRL with a pilot-scale combustor of this type.

A detailed design was prepared by contract. Main features of the facility are:

- combustor inside diameter of 400 mm,
- combustor height of about 7 m,
- variable heat extraction from the combustor by means of retractable bayonet tubes, and
- capability to feed coal, limestone, and ultimately, biomass and liquid fuels.

All major components, such as the combustor and cyclone assembly, baghouse, conveyors, cooling tower, ash handling equipment and instrumentation have been procured. Substantial building modifications are required, and design work on these is essentially complete, but financial constraints precluded the commencement of construction in 1986/87. Meanwhile, final structural, piping, electrical and instrumentation drawings have been prepared by contract. It is hoped that substantial progress in erection can be accomplished in 1987/88.

Bench-Scale Program

Coal reactivity parameters

The wide range of coals available in Canada which may ultimately find application in FBC systems makes it highly desirable to be able to obtain quickly and economically some measure of their relative performance. Accordingly, CCRL undertook to develop a bench-scale FBC and an empirical procedure for ranking the reactivity of coals and other fuels.

The apparatus was commissioned in 1982. Subsequently a procedure was developed whereby fuel is batch-fed to the preheated combustor, and the rate of CO_2 evolution is used as a measure of reactivity. A sophisticated flue gas analysis system coupled with computerized data processing provide a rapid, inexpensive test procedure. Results are evaluated in terms of a parameter called the mean carbon residence time.

Calibration tests on five commercial coals having well-known reactivity characteristics with respect to conventional combustion techniques demonstrated the validity of the procedure. This work was reported at the American Institute of Chemical Engineers Conference in Miami, Florida, November 1986, and has also been published as a division report.

Reactivity tests have been conducted on four samples of Prince coal from Cape Breton, N.S. One sample was raw coal, two were washed (specific gravities of 1.27 and 1.67) and one was washery rejects. Further tests have been carried out on an oxidized sample of the coal washed at

1.27 specific gravity. The results are expected to elucidate the effects of ash content on reactivity.

In order to establish the effects of abrasion on fuel particle size, the equipment was modified to improve the fuel feed system and permit recovery of the bed material at various stages of the combustion process.

The main objective of the reactivity work is to develop a sound basis for mathematical models to predict fluidized bed combustion performance.

SO_2 sorbent reactivity

Early work on sulphur capture in fluidized bed combustion showed that limestone and dolomite vary greatly in their ability to react with SO_2. For example, to achieve a given level of sulphur capture, stone from one deposit may require a Ca/S ratio of 2 whereas that from another may require a Ca/S ratio of 5. Differences are related primarily to the porosity and hardness of the stone because they affect the surface area available for reaction with SO_2.

In 1982, CANMET's Mineral Sciences Laboratories (MSL), in cooperation with CCRL, undertook to develop a database of the sulphation capacities of various Canadian limestones likely to be utilized in fluidized bed combustion. Having established that thermogravimetric analysis (TGA) techniques do not always provide reliable results because they do not simulate the dynamic conditions of a fluidized bed, MSL developed a bench-scale fluidized bed apparatus and a procedure which closely simulates full-scale conditions. About 30 Canadian and some foreign limestones were evaluated, and the results were verified, where possible, against those from full-scale experience.

It was shown that surface area was the dominant factor affecting sulphation capacity. Subsequent work showed that limestones, which have a low reactivity in their natural state, can be rendered substantially more reactive by grinding to less than 0.15 mm, then pelletizing to 2 to 6 mm typically required by a bubbling fluidized bed. The pelletized material has larger pores hence more effective surface area than the native stone.

It was also established that the ash constituents of coal may enhance or reduce the sulphation capacity of limestones. For example, the iron compounds commonly found in coal ash generally have a negative catalytic effect. The MSL limestone evaluation procedure has therefore been modified so that it can be carried out in the presence of ash from the coal with which it will be fired.

In addition, evaluations were carried out on two New Brunswick limestones in support of the Chatham circulating FBC demonstration which is described later. The effect of limestone particle size was a parameter of major interest in this study.

The limestone reactivity work is now considered sufficient to meet the needs of at least the next few years. A CANMET report,

summarizing the information developed over the past few years, is in the final stages of preparation. The bench-scale reactivity apparatus is available to evaluate additional sorbents as the need arises. The Risoe National Laboratory of Denmark has adopted CANMET's approach for evaluating the reactivity of limestone.

Bench-scale circulating FBC

Circulating FBC is perceived as the most promising technology for the utilization of residues such as coke and pitch from the upgrading of tar sands and heavy oil. However, these materials contain relatively high concentrations of alkali and vanadium, which may cause boiler tube corrosion.

In FY 1984/85, MSL undertook to build a 50-KW, 100-mm diam. circulating FBC and to investigate the fate of vanadium, nickel, sulphur and alkali when upgrading residues are fired with limestone as sulphur sorbent. In the past year a substantial experimental program was carried out with Syncrude coke and Fort McMurray limestone as feedstock. It was found that over 90% of the nickel and vanadium was consistently fixed in the residues. This indicates that the usual corrosion caused by elements is substantially eliminated in fluidized bed combustion. This was confirmed by the evaluation of corrosion probes which were exposed to about 125 h of coke combustion. Corrosion problems were found but were related to the presence of sulphur and sulphates, with neither nickel nor vanadium playing a role.

Analysis of FBC residues

Fluidized bed combustion, particularly when limestone is added to achieve sulphur capture, presents special problems in the analysis of combustion residues. For example, carbon content of the solid combustion residues must be determined in order to establish boiler or combustion efficiency, but the residues may contain up to 40% CaO, which is a powerful desiccant even at 515°C. Thus, samples may take up atmospheric moisture during any stage of the sampling, preparation and ashing processes.

Experiments have been carried out over a range of temperature and relative humidity conditions to determine the rate at which samples pick up moisture. This has made it possible to prescribe sample collection, storage and preparation procedures which minimize error. With respect to fixed carbon determination, absolute results can be obtained using a thermogravimetric-differential thermal analysis technique. This has been applied by MSL to develop an understanding of the mechanisms taking place, and to corroborate the validity of an acid extraction technique which removes carbonates and reacted CaO prior to ashing. As an alternate method of completely dissolving solid samples with minimum contamination, and/or elemental loss, CCRL has been experimenting with microwave digestion, employing hydrofluoric acid. Results have been encouraging. Also, CCRL has ordered an inductively-coupled plasma spectrometer, which will greatly enhance the capability for trace element analysis.

Unfortunately, most of the analytical techniques described above are not ASTM standard procedures. Primary responsibility for having them accepted by ASTM, and further development of analytical techniques appropriate to FBC residues, has been transferred to the newly-formed Fuels Characterization Research Laboratory of ERL.

CONTRACT R&D ON FLUIDIZED BED COMBUSTION

Queen's University - Fluidized Bed Combustion

Queen's University has been conducting extensive and varied research in FBC under contract since 1981, using a pilot-scale combustor essentially identical to the CCRL Mark II facility. The present contract, covering two years, encompasses about $450 K of work to be completed by March 1987.

The first year's work concentrated on combustion tests with Lingan coal (a bituminous coal from Nova Scotia) with Irish Cove limestone as the sulphur sorbent. The main objective was to confirm the relatively low combustion efficiencies of 80 to 85% which were obtained with the same feedstocks in the 10,000 h corrosion test program carried out using a 1 m^2 test facility at Point Tupper, N.S. Some combustion tests were also carried out with a North American anthracite to help clarify the mechanisms of char combustion. Concurrently, more fundamental work addressed the difficult task of developing mathematical models to describe fluidized bed combustion. This work forms part of Canada's contribution to the International Energy Agency (IEA) Agreement on AFBC. Specific topics studied were the formation of a volatiles plume in the bed, solids elutriation, freeboard combustion, and residence time of large fuel particles in the bed.

In the past year, a series of combustion trials was carried out on coal/water fuels, to expand information obtained from a previous CANMET contract to Babcock and Wilcox Canada Ltd. Fundamental studies on the combustion of large particles were continued and resulted in the award of a doctoral degree. With respect to mathematical modelling, important information arising from this work is the fact that coals of similar rank can burn according to substantially different mechanisms. For example, of two Eastern Canadian high volatile bituminous coals, particles of one burned according to a shrinking core model whereas particles of the other developed cenospheres. Other work addressed combustion-assisted attrition of coal particles and particle transport in the freeboard. Development of a three-dimensional model of AFBC combustion resulted in another doctoral thesis; this work is being further refined to take into account the movement of large coal particles in the bed, and its effect on mass transfer and the evolution of a volatiles plume.

Queen's University - ASPEN Simulation

ASPEN is a comprehensive computer model for simulating industrial processes. Its main value is in design optimization. Through the Unsolicited Proposal Program, Queen's University was contracted in 1984 to simulate the Summerside FBC boiler plant, using the ASPEN program, and

thus provide a powerful, reliable tool for costing and optimizing new FBC installations.

In the past year, the final step of comparing the model results with actual plant data was completed, and the final report was delivered.

Polymath Corp. - Circulating FBC Tests with Syncrude Coke

A contract sponsored by CANMET in 1981 demonstrated that Syncrude coke could be burnt efficiently, with excellent sulphur capture, using circulating FBC technology. Since the utilization of such fuels is of continuing interest to governments and industry, it was deemed desirable to follow up the initial work with a more comprehensive pilot-scale study, which would employ Fort McMurray limestone as the sulphur sorbent, and would provide a more complete materials balance, including information on the fate of heavy metals.

In March 1985 a contract for such a study was awarded to Polymath Corp., which subcontracted the pilot-scale testwork to A. Ahlstrom Ltd. of Finland. About 50 tons of Syncrude coke and 30 tons of Fort McMurray limestone were shipped to Finland for the combustion tests, which were successfully completed in January 1986. The final report, received in the summer of 1986, showed that a circulating FBC can burn Syncrude coke with combustion efficiencies of 98 to 99%, that 90% sulphur capture can be achieved using Fort McMurray limestone at a Ca/S ratio of about 1.7, and that potentially-corrosive vanadium and nickel in the coke are, for the most part, trapped in the solid residues. Furthermore, A. Ahlstrom Ltd. is of the opinion that sufficient information is now on record to tender a full-scale boiler for these feedstocks with normal commercial warranties.

The final report has been distributed to interested companies in the oil sands/heavy oil industry, and forms the basis of a paper accepted for presentation at the 9th International Conference on Fluidized Bed Combustion, May 1987, in Boston, Massachusetts.

University of British Columbia - Circulating FBC of Pitch and Tar Materials

In 1985 the University of British Columbia submitted an unsolicited proposal to conduct a program of combustion tests in a 150-mm diam. pilot-scale circulating FBC. Proposed feedstocks included coal, wood waste and two types of residues from heavy oil upgrading. Since circulating FBC of residues is perceived to be of considerable interest to the heavy oil/tar sands industry, CCRL, upon review of the proposal, recommended acceptance, and a contract was awarded early in 1986, for completion by July 1987.

To date combustion tests have been completed on a Western Canadian anthracite and on hogged wood waste. A supply of CANMET pitch has been obtained from the Petro Canada demonstration upgrader in Montreal, and negotiations are underway to obtain a second pitch from another upgrading process.

Under an amendment to the contract, UBC also carried out combustion trials with Minto coal and Elmtree limestone, both from New Brunswick. The main objective was to generate residue samples at three different Ca/S ratios, in support of an Environment Canada-sponsored investigation into the problems associated with disposal of residues from the circulating FBC demonstration plant at Chatham, N.B.

Engineering Evaluation of Fluidized Bed Boiler Demonstration Plant at CFB Summerside, P.E.I.

The fluidized bed boiler demonstration at CFB Summerside has been in operation since December 1982 and is described later. During that time a wide range of operating problems were successfully resolved. The most serious was the erosion of heat transfer surfaces exposed to the bed. To ensure that this experience is thoroughly documented for potential users, CCRL contracted out the preparation of a comprehensive report describing:

- the history of boiler tube erosion and the measures taken to mitigate it, and

- the operating history of the FBC plant in general, and the numerous modifications made to improve performance.

A contract in the amount of $78 K was awarded to Monenco Consultants Ltd. to collate data from the boiler supplier, the plant operating staff and CCRL files. The final report is expected soon.

Coal Feeding Trials with the Staketech COAX Press

Some years ago Stake Technology Ltd. (formerly based in Ottawa, now in Oakville) developed a process for converting waste biomass such as hardwood chips and sugar cane bagasse into high quality cattle feed, essentially by steam cooking at elevated pressure. A key component of the process is a patented feeder, the COAX press, which injects the feedstock into the high-pressure reactor. It was brought to the attention of CCRL that the COAX press might offer a means for feeding coal into pressure vessels such as gasifiers and pressurized fluidized bed combustors that would be substantially superior to presently available technology.

Under CANMET-sponsored contracts in 1980 and 1984, bench-scale tests were carried out which defined the gas permeability of coal plugs formed at various conditions of pressure, thickness, coal size, and moisture content. This work proved the validity of the concept; what remained was to conduct trials with a full-scale press, in order to establish the in-situ permeability of the formed coal plug and the effects of friction on power requirement and wear.

Late in 1986 Staketech Ltd. submitted an unsolicited proposal to carry out feeding trials with coal on a full-scale feeder. Under a cooperative program Staketech would install the press along with suitable coal handling equipment, on CANMET premises for a one-month period,

operate the press and carry out in-situ gas permeability measurements. CCRL would provide the coal, carry out all analytical work, and write the final report. A contract has been awarded and the work will be carried out in the summer of 1987.

DEMONSTRATION OF FLUIDIZED BED COMBUSTION

FBC Heating Plant at CFB Summerside

Since 1977, EMR has been collaborating with DND in the construction and demonstration of a fluidized bed heating plant at CFB Summerside, P.E.I. EMR's technical input to the project has been almost entirely through CCRL, which coordinated the design contracts and, following completion of plant construction in December 1982, planned and conducted the demonstration program.

The plant consists of two boilers, each rated at 18 t/h of steam. They were designed to burn high-sulphur Eastern Canadian coal, with at least 80% sulphur capture by means of limestone addition to the bed. An additional requirement was that they be capable of co-firing wood chips to provide up to 30% of the heat input at any load.

During the first and half of the second heating seasons (82/83 and 83/84) efforts were concentrated on overcoming operating difficulties, primarily in materials handling, calibration of the automatic controls, operator training, and boiler acceptance tests, all with coal as the only fuel. By May 1984 the boilers had been tested with three different Cape Breton coals having sulphur contents ranging from 4 to 6%, and guarantees of capacity, efficiency and emissions control had been met with all of them. Also in May 1984 some brief tests showed that over 50% of boiler capacity could be achieved firing wood chips alone.

As might be expected in the demonstration of a new technology, operating problems were numerous, and sometimes severe. A major concern was wastage of the waterwalls and in-bed tubes exposed to the erosive action of the fluidized bed. The first indications of erosion appeared after only a few hundred hours of operation. Various corrective measures were implemented during the period from 1983 to 1985, none of which proved completely satisfactory. Therefore, during the summer of 1985, closely spaced studs, about 10 mm diam. by 20 mm long, were spot welded to the waterwalls from the level of the distributor plate to a height of about 2 m. At the same time, 10 mm diam. longitudinal rods were welded to the in-bed tubes. These measures seem to have essentially solved the problem. During the 1985/86 heating season, each boiler was operated for approximately 5000 h with no tube wastage and only minimal erosion of the protective hardware. Boiler performance was also improved significantly.

To improve combustion efficiency and sorbent utilization each boiler is equipped with two fly ash reinjection systems. When installed each employed high-velocity pneumatic transport. These systems required excessive maintenance due to erosion. In May 1985 an erosion-caused fault in one reinjection system led to destruction of an induced draft fan. In the summer of 1985 one reinjection system on each boiler was replaced by a

novel CCRL design which employs simple hardware and low-velocity transport of the fly ash up to the point of injection into the furnace. These systems functioned well throughout the 1985/86 heating system with no significant erosion. Patent protection has been applied for.

Numerous other modifications have been made, and will be described in a consultant's report on the operating history of the plant described earlier.

CANMET's formal demonstration program on the FBC boilers at Summerside ended with the 1985/86 heating season. However, further modifications to improve plant performance and reliability were carried out during the summer of 1986. The most important of these were:

- The two remaining original fly ash reinjection systems were replaced with systems of the CCRL design.

- The in-bed tubes on both boilers were replaced. In one boiler, the new tubes are conventional carbon steel, protected by longitudinal rods. In the other boiler, six tubes are likewise carbon steel with longitudinal rods, six tubes are carbon steel protected by 10 mm diam. by 20 mm long studs, and six tubes are T9 alloy, without protective hardware.

- The outdoor ash silo was insulated to minimize ash handling difficulties caused by condensation.

- Longer bags and cages were installed in the baghouses to improve particulate cleanup and bag life.

CCRL will continue to monitor the performance of the plant, particularly with respect to the relative erosion resistance of the three recently installed configurations of in-bed tubes. Plant operation during the current heating season has been uneventful to date.

In February 1986 a contractor for the US Environmental Protection Agency (EPA) conducted a 4-week program of emissions testing on the fluidized bed boilers at Summerside. The objective was to demonstrate the SO_2 and NO_x reduction capabilities of FBC under normal industrial conditions, and EPA requested permission to monitor the Summerside plant to take advantage of the extensive flue gas analytical system which CCRL had installed for the duration of the demonstration program. The EPA tests demonstrated that with a coal containing 5.5% sulphur, feeding limestone at a rate to provide a Ca/S ratio of 3, routinely achieves 80% sulphur capture. This meets the Environment Canada guideline. Increasing the Ca/S ratio to 4 routinely achieves a sulphur capture of 90% or better. This information is being used by EPA to help establish new source performance standards for small boilers. These results also provide independent confirmation of the capability of FBC technology to control SO_2 emissions from high sulphur coal, and the value of the CFB Summerside demonstration.

Circulating FBC Utility Boiler Demonstration at Chatham, N.B.

In August 1984, Treasury Board approved EMR Coal Division funding of a major demonstration project - the construction of a 20 MWe circulating FBC utility boiler at the Chatham generating station of New Brunswick Electric Power Commission (NBEPC). Besides being the largest FBC boiler yet built in Canada, and the first to operate at the high steam pressure and temperature conditions required of utility boilers, this unit will be unique in that it will be co-fired with New Brunswick high-sulphur coal and oil shale. The latter feedstock serves both as supplementary fuel and, because of its inherent calcium content, as supplementary sulphur sorbent.

The project is managed by NBEPC, and the contract for design and construction of the circulating FBC boiler was awarded to Combustion Engineering Canada Ltd. in collaboration with Lurgi GmbH. Site preparation was begun in the spring of 1985, with completion scheduled for June 1986. Unfortunately, progress was delayed by a fire in May 1986, which destroyed much of the equipment in the control room. Construction was completed in November 1986. Commissioning of the unit is in progress. Acceptance tests will be carried out, and a demonstration program is expected to begin early summer 1987.

CCRL is a member of the Management Committee which directs the project, and is also involved at other levels. It chairs the Technical Committee which is responsible for detailed planning of the demonstration program. CCRL will have the further task of interpreting or otherwise commenting on the data from the demonstration program. Substantial assistance was provided in planning the chemical analysis facilities for the plant, and CCRL has prepared a procedures manual for analysis by atomic absorption spectrophotometry of Ca and Mg in fuel and combustion residues. Computer algorithms for determining boiler efficiency have been reviewed in detail, and assistance has been given in developing numerous test procedures. The demonstration program is likely to be partially supported by the CANMET Energy Conversion Cost-Shared Program. CCRL was also represented on the Steering Committee for a contract, sponsored by the Canadian Electrical Association, which investigated the utilization of residues from circulating FBC boilers. It now serves on a committee formed by Environment Canada to carry out further work on safe disposal of residues.

TECHNOLOGY TRANSFER IN FLUIDIZED BED COMBUSTION

IEA Agreement on AFBC

In 1980, under the auspices of the International Energy Agency (IEA), nine nations including Canada signed the "Implementing Agreement for Cooperation in the Field of Atmospheric Fluidized Bed Combustion in Industrial or District Heating Boilers". Canada's participating projects are all CCRL projects, i.e., the CFB Summerside demonstration, the CCRL in-house R&D program, and the R&D program contracted to Queen's University. Therefore the Canadian representative to the Agreement has

also been from CCRL. Four other nations are in the process of joining the Agreement.

Besides sharing information on their participating projects, the members of the Agreement have undertaken to develop a mathematical model of fluidized bed combustion, which hopefully can be evolved into a powerful tool for designing FBC boilers. Canada's contribution to this effort has been a model developed at Queen's University as part of a doctoral program. Scientists in Denmark, Sweden the Netherlands and the Federal Republic of Germany have been running the Canadian model to compare its predictions with results from their own combustors, and to establish its suitability for further development.

Two sets of technical and executive committee meetings were held in 1986; one in May in Vienna, Austria, and the other in November in Liège, Belgium. At the meeting in Vienna, the CCRL representative described the successful resolution of the erosion problems at the Summerside FBC plant. Because of financial constraints, Canada was not represented at the meeting in Liège.

INDUSTRIAL COMBUSTION PROCESSES

The role of the Industrial Combustion Processes Section is to aid Canadian industries and utilities in the process of converting from premium fuels to indigenous and often low quality coals. In many cases, these coals are from newly-developed deposits which have unknown characteristics. Reliable data on their combustion heat transfer and emission characteristics are non-existent. The CCRL coal combustion research program reflects the increasing importance of coal in our domestic energy requirements and also supports Canadian coal exporters in their drive to secure a reasonable share of the world market. An industry/government collaborative program has been established in which the utilities and coal suppliers participate under the CANMET Minerals and Earth Science Program. An in-house research program has also been established to increase the fundamental knowledge and expertise in coal combustion.

CONVENTIONAL COMBUSTION

The basic objective of conventional coal combustion is to study the combustion performance, heat transfer and emission characteristics of Canadian coals and rejects for conventional power generation and industrial use, both in Canada and in support of the export market. Specifically to:

- produce a periodically updated reference databank of the combustion performance and emission characteristics of commercially important Canadian coals;

- collaborate with industry in the determination of significant combustion performance characteristics of newly developed coal deposits for electrical power generation and industrial use;

- assess the effects of coal cleaning on the flame heat transfer, deposition and emission characteristics of Canadian thermal coals for utility and industrial applications;

- conduct fundamental studies of the ignition, devolatilization and combustion burnout of unreactive Canadian coals and reject materials.

Low-Grade Coal for Electrical Generation

The general objectives are to evaluate the combustion, slagging and fouling properties of coals from Canadian coal deposits for use in power utility boilers and to minimize emissions from conventional coal combustion furnaces by control of flame properties through burner and furnace design, chemical additives, flue gas cleanup and coal feed comminution. Specifically to:

- determine the combustion and handling characteristics of the coal;

- evaluate the combustion performance at various feed fineness and excess air levels;

- characterize the particulate and gaseous pollutants generated during combustion;

- assess the slagging and fouling potential of ash constituents on radiant heat transfer surfaces and superheater tubes respectively;

- determine the fly ash resistivity characteristics and the ease of fly ash collection by electrostatic precipitation;

- develop combustion charts for each coal or coal blend studied.

The equipment used to investigate these properties is a pulverized coal-fired pilot-scale utility boiler. It embodies two opposed low-swirl burners and has a full-load firing rate of 2.5 GJ/h. The twin burners can be located in three basic positions on the furnace to vary the combustion chamber residence times. It is estimated that at 90 kg/h feed rate and 30% excess air, the residence time can be varied from a minimum of 1 s to a maximum of 3 s, depending on where the burners are located.

During 1986, 25 coal burns were performed in the pilot-scale utility boiler. Six were undertaken as a cooperative coal combustion project with a Western Canadian coal company. Eleven were performed on behalf of an IEA investigation into the effect of coal cleaning on the combustion properties of coals. Two burns were concerned with an on-going in-house project to determine the effect of blending and residence time on coal combustion efficiency. Six burns were executed, as an in-house project, to enhance the combustion efficiency of a low-volatile Western Canadian coking coal through utilization of increased residence time and blending with a high quality thermal coal.

The IEA work is continuing in house. The in-house assessment of boiler performance, as related to comminution and residence time, has been delayed due to higher priority projects. Two reports on cost-shared projects were completed and issued to the companies concerned, two reports on the IEA investigation were issued and three IEA reports are in preparation.

Coal as a Substitute for Oil in Industry

To facilitate the substitution of oil with coal in industrial combustion systems, the combustion and heat transfer characteristics of coals are investigated in the CCRL tunnel furnace and then compared with fuel oil burned under similar aerodynamic conditions. The tunnel furnace (1 m diam. and 4.25 m long) with a refractory precombustion chamber (1.2 m long) is constructed as a series of 28 calorimeters, making it possible to measure the heat absorbed by each 15-cm increment of furnace length. An access slot, with a series of water-cooled doors, permits flame and combustion gas probing along the full length of the furnace, even when the combustion system is under pressure. The tunnel furnace is designed to fire pulverized coal, light and heavy fuel oil, natural gas, biomass products and coal-liquid mixtures at an input rate of about 2 GJ/h.

Gas probes can measure a range of parameters which define spatial temperature, flow and concentration profiles within the furnace atmosphere together with emission levels at the furnace exit. Heat transfer, both convective and radiative, can be measured along the length of the flame. The furnace can also be partially refractory-lined to simulate a number of industrial process heater configurations ranging from boilers (unlined) to kilns (80% lined). Thus, a number of industrial configurations using various feeds and comparative burner assemblies can be studied.

The CCRL tunnel furnace was utilized periodically over four months, firing with No. 2 and No. 6 fuel oil, to aid in the experimental development of a pilot-scale burner/swirl-generator, which could be used to fire a coal-water fuel in the pilot-scale utility boiler. Preliminary experimental photographs of an oil-flame were obtained with a high-speed movie camera using a laser Schlieren technique for back-lighting.

Laser Diagnostic Techniques for Fossil Fuel Flames

A significant effort is underway to develop non-intrusive diagnostic techniques at CCRL. These probing techniques are intended to replace conventional methods of taking measurements in a flame. The current methods of measuring temperature and species concentration require that a probe be immersed in the flame to the test point. The mere presence of the probe in the flame causes a disturbance to the velocity and temperature fields. As such the measurement recorded may not be representative of the situation in the flame. This problem coupled with the inherent errors in the measurement technique itself can result in large errors when using the classical measurement methods. Furthermore, the errors tend to be largest in the areas of greatest interest to the combustion scientist such as recirculating flow.

Optical diagnostic methods eliminate these errors and also provide a better quality measurement. Because the optical techniques use light, they do not disturb the combustion process in the test section. High power pulsed-lasers are generally used as the probe beams. These lasers have an 'ON' time of about 10 ns and oscillate at about 10 Hz. As a result the measurement is frozen in time and vast amounts of data can be collected at any one test point in a very short time. Measurements taken with these non-intrusive techniques allow for the calculation of probability distribution functions and turbulence quantities such as Reynolds shears and stresses. Thus better measurement through modelling techniques will give the scientist a better understanding of the physical processes that occur in the flame.

The Coherent Anti-stokes Raman Spectroscopy (CARS) technique can be used to measure temperature and species concentration in a combustion environment. The laser Schlieren technique is used to visualize the phenomena that occur in flames generated in the laboratory. The laser doppler anemometry (LDA) technique is envisioned for measuring gas velocity and particle size distribution.

The development of the CARS technique has progressed on two fronts: (1) special optics are required to generate the laser probe beams and to measure the resulting CARS beam; (2) sophisticated computer hardware and software are required for the high speed acquisition and analysis of the CARS signals. Both areas of endeavour have progressed to the point of demonstration in bench-scale flames.

The characteristics of the source and detection side optics have been studied using equipment and software developed in-house and under contract. These experiments included studies of the temporal and spectral profiles of the two probe beams, the dispersive and resolution characteristics of the spectrometer grating, and the noise and on-linearity characteristics of the optical multichannel detector. The effects of the detector non-linearity and noise on the accuracy of the temperature measurements are being studied.

The necessary electronics for the synchronization of the source and detection side electro-optics have been installed. The CARS setup is undergoing experiments to demonstrate the technique. Some refinements have been identified for the optical arrangement and are being implemented.

Experiments were conducted to determine the viability of the Schlieren flow visualization technique in coal flames. This technique uses an argon ion laser to back-light the flame. By using high speed photographic techniques and optical filters, the influence of the flame on the laser light can be recorded on film. These pictures give an indication of the flow structures in the flame and will aid in the study of the flame mixing processes. By using the appropriate optics, the combustion process of individual coal particles can also be studied.

Experimental work has determined that due to the characteristics of the laser light conventional Schlieren optics may not be used. Thus alternative optics are being developed for use with the laser Schlieren experiment. These alternatives are being tested in a small-scale coal burner.

Computer Modelling of the CCRL Tunnel Furnace for Powdered Coal Firing

The existing computer code is based on the 'Teach' program of Imperial College and includes the necessary models to simulate combustion of coal. The objective is to improve the program and to expand its capability to handle low-volatile coals.

The program has been improved by incorporating user friendly routines and current models which describe the physical processes in the coal flames and by modularizing the sub-routines. A sophisticated display package is also being incorporated into the coding. However, because of a scarcity of data experiments were conducted using reference and low-volatile coals to generate a data package to validate the computer program.

Comparisons have been made using the experimentally generated data and the output from the computer program simulation. The program has been successful in modelling the conditions inside the tunnel furnace given the limitations of the measured data. Experiments are being planned to address specific questions resulting from the latest validation efforts.

COAL-LIQUID MIXTURE COMBUSTION

The use of coal to replace premium fuels such as gas and oil is an objective of Canadian energy policy but has been inhibited by the inconvenience of handling solid fuel and by its environmental implications. EMR's strategy for energy intends to remove this inhibition by bringing new coal utilization technologies that have both economic and environmental advantages over premium fuel alternatives to a stage useful to industry. The development and commercialization of fuels made from coal-liquid mixtures involving easy, economic coal handling and minimal environmental impact have been major EMR/CANMET objectives.

Specifically, the objective is to develop and evaluate coal-liquid mixture (CLM) preparation and combustion technology as an alternative to the use of premium liquid and gaseous fuels in Canadian utility and industrial applications and where conventional coal combustion technology cannot be readily used. The program will:

- establish a database of the combustion, heat transfer and ash deposition characteristics of a numnber of CLM fuels through contract and in-house research, and in collaboration with foreign agencies;

- study, by contract, the potential derating effects of the conversion of oil-designed boilers to CLM fuels;

- provide technical support to the coal-water fuel (CWF) demonstration programs being sponsored by EMR's Coal Division at the Maritime Electric Generating Station, Charlottetown, P.E.I.;

- participate, on behalf of Canada, in the International Energy Agency CLM Implementing Agreement and its annexes in the development of both in-house and contract programs to resolve the problems of reduced burner life through abrasive wear, poor atomization performance and carbon conversion efficiency as well as resolution of the relationships between slurry rheology, handling characteristics and atomization quality;

- participate with industry in other programs which would endeavour to develop CLM technology for process heating purposes.

Maritime Electric Generating Station, Charlottetown, P.E.I.

An agreement between Maritime Electric, NBEPC, Cape Breton Development Corporation and EMR was signed September 1, 1985 to demonstrate CWF combustion technology in an oil-designed 20 MWe front-wall fired boiler. Burner selection was made in March 1986 and five burners have been installed on the unit for performance data on CWF and oil. It is expected the test program will be completed by the end of 1987. It is also planned to test the EMR/CANMET wear-resistant ceramic burner in 1987.

CONTRACT R&D

Canada Cement Lafarge has successfully converted its wet process cement kilns to on-site prepared CWF, therebyd displacing natural gas economically. CANMET and NRC have contributed to the development of wear-resistant ceramic atomizers for this application which have improved combustionh and atomizer life. The company has made the commercial decision to continue using CWF in the plant as long as it remains economically attractive. The final report on the contract coal has been received and CCRL is in the process of evaluating other coal feedstocks for the CWF application.

The combustion of CWF with different ash levels in a pilot scale test rig designed to simulate conditions typically encountered in convective heat transfer surfaces in oil-designed utility boilers has been carried out at the Centre for Energy Studies, Technical University of Nova Scotia. This work was intended primarily to evaluate the characteristics of CWF ash deposited on heat transfer tubes, their susceptibility to soot blowing and their impact on heat transfer and erosion. The study demonstrated that CWF ash deposits on heat transfer surfaces were benign and could be easily removed by soot blowing with no long term detrimental effects on heat transfer or erosion. The project was funded by the Canada-Nova Scotia Oil Substitution Agreement with technical direction under the supervision of EMR/CANMET scientists and a representative from the Nova Scotia Power Corporation.

The atomization characteristics of CWF and the performance of generic CWF atomizers were evaluated under contract at the Nova Scotia Research Foundation Corporation. The project was funded by the Canada-Nova

Scotia Oil Substitution Agreement and was carried out under the technical supervision of EMR/CANMET. Design construction and commissioning of the spray test facility were completed in mid-1986 and a major program of work designed to evaluate the mechanism of CWF atomization, the influence of fuel properties and the operating characteristics of commercial CWF atomizers is being completed. The spray test facility has proven to be a very valuable link in providing data in support of the ongoing CWF demonstration program in Charlottetown, PEI, and in the optimization of the CWF production and fuel preparation techniques in the CWF production plant operated by the Cape Breton Development Corporation in Sydney, NS.

ABATEMENT OF COMBUSTION-SOURCE EMISSIONS

The clean use of coal for electricity generation and process steam has been designated as a high priority for combustion research, development and demonstration in Canada and the US because of a mutual interest in reducing the transboundary flow of industrial stack gases. In addition, European concerns regarding the long-distance transport of acid rain have resulted in collaborative projects to suppress both SO_x and NO_x emissions from pulverized-coal fired boilers under two International Energy Agency agreements.

Canadian industry, which accounts for less than 15% of the total US/Canada acid rain inventory, is actively pursuing economical and technically reliable technology options for burning coal cleanly in existing combustion units. The use of retrofit technology, although more difficult to apply than newly-designed systems, will impact immediately and positively on achieving long-term targets for controlling potentially deleterious emissions and for disposal of the neutralized products.

CONTRACT RESEARCH

Gagetown Demonstration

The two novel staged-pulverized-coal burners installed on Unit No. 2 at the Central Heating Plant of CFB Gagetown were modified to improve their combustion performance. The performance of the retrofitted burners is now comparable to that of the conventional burners on Units 1 and 3, but with the added advantage of a higher boiler efficiency. Field experiments, which are restricted to the November-March heating season, are now in progress to evaluate NO_x/SO_x reductions during burning of Maritime coal. The data acquired will be used to "fine tune" the burner design so that optimal performance can be obtained with coals containing less than 3% sulphur. Stack gas emissions are being measured under a cooperative project with Environment Canada and all changes to the combustion and sorbent injection hardware are being installed by the Department of National Defence. Boiler efficiency calculations and field coordination are being done under a contract with G.A. Robb Associates.

Chatham Small-Scale Burner Facility

The unit, rated at about 0.4 MWt of coal, was successfully commissioned during the year on coal only and on a coal/sorbent combination. A number of design deficiencies were resolved including the provision of a uniform pulverized coal and powdered sorbent feed and the use of in-flame probing and sampling devices. The utility staff at Chatham are proficient in the operation of the facility and are ready to accept contract work from sources other than EMR.

The research program performed for CANMET involved a number of screening trials to establish the operational limits of the pilot-plant design and the capability of the facility to simulate combustion conditions in industrial flames. A report on this contract will be available in early 1987.

Boundary Dam Demonstration

Under a $2.2 million contract co-funded by five agencies, including EMR Coal Division and CANMET which provided $200 K, the Saskatchewan Power Corporation and Combustion Engineering Canada conducted extensive trials at Boundary Dam Generation Station to evaluate NO_x/SO_x reduction in a lignite-fired boiler. The four-phase field program using both Boundary Dam and Shand lignite in combination with limestone or calcium hydrate to suppress SO_x and air staging to suppress NO_x was completed in July 1986.

Three drafts of the final report on the project were reviewed by a technical committee represented by CANMET, Environment Canada and the Canadian Electrical Association and detailed comments were provided to the contractor. The project has demonstrated the benefits and limitations of in-furnace control of acid rain precursors and identified a number of knowledge gaps that will be addressed next year.

Rockwell Burner

The slagging burner concept is being strongly promoted by TransAlta Utilities which is heading a consortium to develop and demonstrate application for utility boilers. Development work on a pilot scale combustor has indicated that Alberta plains coals containing high inherent calcium can be burned without sorbent injection to control SO_x and that NO_x levels can be reduced to less than 150 ppm.

The next stage of the project is to install a 29.4 MJ/S burner for field evaluations at Wabamun Generating Station. CANMET recently awarded a contract to TransAlta for $238 K under the 50/50 Coal Conversion Program for the integrated engineering design of the fuel injector system, the combustion chamber and the slag removal assembly.

TECHNOLOGY TRANSFER

Canadian Electrical Association

CANMET together with EMR Coal Division serves on the Expert Panel on Emission Control Technology of the Canadian Electrical Association (CEA). Four meetings were held:

- to review a number of research proposals submitted for joint CEA/federal funding,
- to visit and evaluate demonstration projects on in-furnace sorbent injection, flue gas scrubbing, coal cleaning and gasification,
- to develop new research proposals for mathematical modelling of furnaces, cold-end sorbent capture and the disposal of wastes from sulphur abatement devices. The panel, which also includes interested utilities and Environment Canada, has provided technical advice on federal clean coal priorities and proposed emission targets and time frames for acid gas reductions from utility plants.

IEA Low NO_x Coal Combustion Agreement

This Agreement is being carried out on a shared-cost basis by Canada, Denmark, Sweden and the USA. Stages I and II are now completed and involved mechanistic and pilot-scale studies of the conversion of fuel nitrogen to NO_x and the use of limestone injection to control SO_x. Stage III, which runs from 1986 to 1988, focusses on the application of the fundamental data obtained in Stages I and II in operational boilers in each country and in the use of the field results to validate a mathematical model for predicting combustion and emissions performance.

CARBONIZATION RESEARCH

In 1985, Canada exported 22 million tonnes of coking coal - about 81% of Canada's coal exports. This represented a 9% increase over the previous year. Most of Canada's coal exports are high-grade coking coals from Western Canada but a new coking coal mine will become operable in Cape Breton, NS. To assist Canada's metallurgical coal producers, ERL provides expertise, laboratory and pilot plant facilities for comprehensive carbonization and cokemaking investigations.

CANMET, as a member of the Canadian Carbonization Research Association, provides all experimental facilities and scientific and technical personnel to assist in planning and carrying out research of immediate interest to both the coal and steel industries. ERL scientists also plan and conduct in-house and contract research activities often of a more national interest.

ENHANCEMENT OF COKING PROPERTIES

Effect of Coking Time on Strength After Reaction (CSR)

A typical coal blend from a Canadian steel company was carbonized at different coking rates and times to determine their effects on the CSR and other coke quality parameters. Results from this study indicated that cokes having higher CSR indices were produced by faster coking rates to 900°C at the centre of the oven and by extending gross coking times to produce higher temperature coke. Faster coking rates produced higher ASTM hardness but lower ASTM stability indices for this coal. The results are important to the Canadian steel producers who are trying to improve CSR values by modifying their coking conditions.

Cage Tests in Algoma Coke Ovens

Investigations on cokes taken from 27 cages inserted into Algoma's 5-m coke oven battery were completed. Cages were installed at three levels below the coal line for all three charge holes. Temperature and pressure data were collected for the same locations. Fourteen tonnes of coal, two tonnes of wharf coke, and 29 cages with coke were collected and shipped to Ottawa for investigation. The temperature data from the Algoma ovens indicated the coal in the bottom of the oven carbonized much faster than that at the top resulting in cokes with higher densities and strength. Pressure data indicated peak gas pressures decreased from the bottom of the oven to the top. Sole-heated oven experiments on the Algoma coal blends indicated that the apparent specific gravity of coke is primarily a function of the load under which it is produced. The blend carbonized in the Ottawa 460-mm wide movable-wall oven indicated:

- coke apparent specific gravity increased with coking rate and oven bulk density;
- coking pressures were affected mainly by changes in bulk density and not coking rates;
- coke stability improved with increased coal bulk density and slower coking rates;
- coke hardness improved with increased coal bulk density and faster coking rates.

Canada's steelmakers have used the results of this study to decrease temperature differences along the height of their coke oven flues to improve coke quality and coking pressures.

REPRODUCIBILITY OF COKE OVEN RESULTS

ERL has an ongoing program to ensure that industry can rely on the accuracy and precision of results from its analytical and pilot plant facilities. Work in the past year compared the reproducibility of results from the Ottawa 310 mm and 460 mm and the Devon Carbolite ovens. All test work in this study is complete. The Ottawa 310 mm oven was the most

reproducible for maximum wall pressure but poorest for coke strength. The two 460 mm ovens produced consistent coke quality indices but wall pressures varied over an extremely wide range. Future investigations will examine why the Devon Carbolite oven generates such low wall pressures. Recently, repeated testing of a blend was undertaken in the rebuilt Ottawa 460 mm oven to determine the repeatability of coke oven results. Since there was concern about the influence of oxidation on results repeat tests were conducted 14 days apart to ensure consistency in testing procedure. This should more clearly identify problems in coking results caused by delays between coal preparation and testing. All results appear to be reproducible except for maximum coking pressure. This repeatability study will be extended to the other pilot plant ovens.

TEST OVEN COKING

The objective is to gain a better understanding of the physical process of coking in a slot-type oven and to extrapolate better coke quality and gas pressures from pilot ovens to the larger industrial coke ovens. Cokes made in slot-type ovens do not have homogeneous properties in the vertical direction. This was shown by pushing intact, the coke cake from pilot ovens into a vessel for dry-quenching and dividing the coke into layers for testing. The investigation was done on four binary coking blends containing from 0 to 40% low-volatile coal. The variations in coke quality in the vertical direction were larger for the lower the coking pressure. This must be allowed for when extrapolating pilot results to full-scale ovens.

INFLUENCE OF COAL PROPERTIES ON CARBONIZATION

Effect of Component Properties on CSR

Many blast furnace operators are now recognizing the coke strength after reaction (CSR) test rather than the ambient temperature coke strength tests, e.g., ASTM stability, as the best method to determine coke quality. Others consider the test to reflect existing criteria thus believe it to be of limited value.

Seven cokes having identical ASTM strengths were made from binary blends under identical carbonization conditions. Four were made from binary blends of seven Appalachian coals having vitrinite reflectances from 0.88 to 1.65. Three were made from binary blends using six component coals from Western Canada having vitrinite reflectances similar to those of the Appalachian coals. CSR properties varied considerably from 48.6 to 69 for the seven cokes having identical ASTM stabilities. No more obvious relationship was found between their texture and CSR and lower reactivity indices than that of the cokes from the Appalachian blends. The differences in these indices were found to be mainly related to the basic components in the coke ash. The high CSR values of most Canadian coals should be advantageous in the world coal markets.

Evaluation of Anthracite Fines as Coking Additives

Minus 30 and minus 60 mesh anthracite fines were added at 0, 5, 7 and 10% of a typical Canadian steel company blend. For both additions

the wall pressure decreased with increasing levels of anthracite, coke apparent specific gravity improved, and ASTM coke stability improved to a maximum at additions from 5 to 7%.

DEVELOPMENT OF METHODS TO PREDICT COKE QUALITY

Improved Definition of Thermal/Metallurgical Coal Interface

Three channel samples of coal were taken across seams from two mines in Western Canada. Samples were taken from a regions containing highly oxidized (thermal) coal, metallurgical grade coal, and partially oxidized coal. Samples of the coal were evaluated by several analytical techniques including chemistry, thermal rheology, oxygen absorption, solvent swelling, DTGA, NMR, FTIR, pH of slurry, alkali solubility, carbonization, coke microscopy, and coke reactivity to determine which method readily distinguishes between metallurgical grade coal and that which has been oxidized or partially oxidized. Most promising techniques for readily identifying oxidation include free swelling indices, oxygen absorption, and alkali solubility. Coke microscopy serves as an excellent reference for determining the absolute amount of oxidation of thecoal. Samples from other mines in Western Canada will be studied.

Factors Affecting the Rheology of Western Canadian Coals

Work performed in house and under contract has shown that existing thermal rheological models using dilatation and fluidity are not reliable in predicting the quality of coke from Western Canadian coals. Appalachian coals have consistently higher dilatations than Western Canadian coals but as demonstrated in several investigations both coals produce high quality metallurgical coke. Although thermal rheological measurements vary, anisotropic coke textures from both coals were similar for similar ranks.

CANMET recently awarded a contract to the University of Waterloo to develop the plastofrost apparatus for identifying differences in the coal to coke transformation between Cretaceous coals from Canada and other world coals. ERL continues to use coke microscopy, and to develop semi-automated and automated methods to quantify the amount of reactive and inert macerals in coals.

CONVENTIONAL COKEMAKING IN SLOT-TYPE OVENS

ERL's technical-scale coke ovens are extensively used by the coal and steel industry to evaluate the coking properties of coking coals and blends having potential commercial applications. These coke oven trials are often supplemented by small-scale tests to measure dilatation and by laboratory analyses to determine the chemical, rheological and petrographic properties of coal and coke. Coal and steel companies rely on these facilities to evaluate and market their coal resources and to evaluate and select the best combination of coals and blends for purchase and operating purposes.

ENGINEERING, DESIGN, CONSTRUCTION AND SUPPORT SERVICES

SUMMARY

Engineering, design, equipment development, and information services were provided to all areas of the division.

The equipment development shop was dedicated during this term to the construction of the coprocessing pilot plant (PP3). Requests for urgent repairs/modifications from other areas were responded to on a priority basis.

Thirty-six projects were initiated requiring Public Works Canada involvement. Discussions and subsequent planning with PWC were undertaken through this section.

The information services arm performed literary editing of all division reports, provided information services, organized numerous tours of the facilities, and was responsible for compiling and editing the division's 1986/87 annual report.

APPENDIX A

PROFESSIONAL, TECHNICAL AND SUPPORT STAFF

PROFESSIONAL, TECHNICAL AND SUPPORT STAFF

D.A. Reeve	B.Sc., Ph.D. (Birmingham)	Director
G.D. Brown*		Secretary

ADMINISTRATIVE SERVICES

L. Patrick	Admin. Officer
A. Baldock	Clerk
J. Gosende	Secretary
M. Grebenc	Clerk
J. Hogan	Clerk
P. Hughes	Clerk
D. Deans	WPO
S. Gilmour	Secretary
L. Forieri	Rec/Ship (Stores)
J. Haw	Secretary
W. Lauzon	WPO
M. Lyttle (Term)	WPO
G. McCallum	WPO
A. van Benthem (Term)	Clerk
B. Vincent	Clerk
M. Roy (Term)	Clerk
A. Splett	Clerk

ENGINEERING, DESIGN, CONSTRUCTION AND SUPPORT SERVICES

L.P. Mysak	Dipl. Mech. Tech. (Algonquin), B.A.Sc., M.Eng. (Ottawa), P.Eng.	Engineer
D.M. Arsenault		Millwright
J.M. Dowdall		Machinist
J.L. Harcourt		Inf. Officer
R.W. Taylor		Technologist

SYNTHETIC FUELS RESEARCH LABORATORY

J.M. Denis	B.A.Sc. (Ottawa), P.Eng.	Manager

Process Development

D.J. Patmore	B.Sc. (Bristol), Ph.D. (Alberta)	Res. Sci.
T.J.W. de Bruijn	B.Sc., M.Sc., Ph.D. (Delft)	Res. Sci.
J. Chase	B.Sc.Chem. (Acadia), B.Sc. Chem.Eng. (McGill), Ph.D. (Univ. of London)	Res. Sci.
W.H. Dawson	B.Sc. (McGill), Ph.D. (Western Ontario)	Res. Sci.
D.D.S. Liu	B.Chem.Eng. (N. Taiwan Univer.), Ph.D. (Dalhousie), P.Eng.	Res. Sci.

* Retired 15/10/86

Process Development (cont'd)

F.T.T. Ng	B.Sc. (Hong Kong), M.Sc., Ph.D (British Columbia)	Res. Sci.
R.B. Logie	B.Sc. (New Brunswick), P.Eng.	Engineer
P.L. Sears	M.A., Ph.D. (Cambridge)	Res. Sci.
R.W. Beer		Technologist
A.J.G. Cooke	Dipl. Mech. Tech. (Algonquin)	Technologist
R.W. Devlin	Dipl. Forestry (Sault Ste Marie)	Technologist
R.S. Eagleson		Technologist
A.J. Kuiper	Dipl. Biochem. Tech. (Algonquin)	Technologist
P.E. Landry	Dipl. Mech. Tech. (Algonquin)	Technologist
R.N.L. Lycette		Technologist
G.J. McColgan	Dipl. Journalism (Algonquin)	Technologist
C.A.W. McNabb	Dipl. Mech. Tech. (Algonquin)	Technologist
P.J. Mulvihill	Dipl. Ind. Chem. (Algonquin)	Technologist
G.J. Noel	Dipl. Ind. Chem. Tech. (CGEP, Hull)	Technologist
V.R. Phillips	Dipl. Mech. Tech. (Algonquin)	Technologist
R.A. St. Louis	B.Sc. (Ottawa)	Technologist

Bitumen/Oil Recovery

D.K. Faurschou	B.A.Sc. (Toronto)	Res. Sci.
A.E. George	B.Sc., M.Sc., Ph.D. (Cairo)	Res. Sci.
J. Margeson	B.Sc. (Carleton), M.Sc. (Ottawa)	Res. Sci.

Analytical Section

R.J. Lafleur	B.A.Sc. (Waterloo), M.Sc. (Alberta), P.Eng.	Chemist
D.M. Clugston	B.Sc., Ph.D. (McMaster)	Chemist
V. Whelan	B.Sc. (Waterloo)	Chemist
E. Kowalchuk		Technologist
L. Brazeau	Dipl. Chem. Tech. (CGEP, Hull)	Technologist
D.J.A. Dion	Dipl. Chem. Tech. (CGEP, Hull)	Technologist
P.M. French	Dipl. Chem. Tech. (St. Lawrence)	Technologist
B. Grossman	Dipl. Chem. Tech. (Algonquin)	Technologist
K.M. Hollington	Dipl. Chem. Tech. (Algonquin)	Technologist
G. Kodybka	Dipl. Chem. Tech. (Algonquin)	Technologist
S. Laplante	Dipl. Chem. Tech. (CGEP, Hull)	Technologist
G.R. Lett	Dipl. Chem. Tech. (Algonquin)	Technologist
R.W. Dureau	Dipl. Chem. Tech. (Algonquin)	Technologist
G. MacDonald	Dipl. Chem. Tech. (Algonquin)	Technologist
N.R. McLean	B.Sc. (Concordia)	Technologist
D. Whitehead		Technologist
I. Clelland	B.Sc. (Guelph)	Technologist
Wen-Fei Ng	(Petro-Canada employee)	Technologist

Coal Liquefaction

J.F. Kelly	B.Eng., Ph.D. (McGill), P.Eng.	Res. Sci.
S.A. Fouda	B.Eng. (Cairo), M.A.Sc., Ph.D. (Waterloo)	Res. Sci.
M. Ikura	B.Eng. (Himeji), M.Eng. (Usaka), Ph.D. (McGill), P.Eng.	Res. Sci.
P. Rahimi	B.Sc. (Iran), M.Sc. (Brock), Ph.D. (Alberta)	Res. Sci.
A.D. Agnew		Technologist
R.F. Campbell		Technologist
D.M. Dick		Technologist
J.E. Whiten		Technologist

COMBUSTION AND CARBONIZATION RESEARCH LABORATORY

G.K. Lee	B.Sc., M.Sc. (Queen's), P.Eng., C.Eng.	Manager
C.J. Adams	B.Sc., M.Sc. (McGill), Ph.D. (McMaster), P.Eng.	Research Coord.

Coal Treatment and Coke Processing

T.A. Lloyd	B.Sc. (Carleton)	Phys. Sci.
J.W. St. James	B.Sc. (Waterloo)	Phys. Sci.
R.G. Fouhse	B.Sc. (Saskatchewan), P.Eng.	Engineer
P.A. Couturier		Technologist
R.K. Graham		Technologist
P. Malaiyandi		Technologist
R.R. Bell		Coke Oven Tech.
R.F. Dowdall		Coke Oven Tech.
D.S. Ketchum		Coke Oven Tech.
V. O'Connor		Coke Oven Tech.
K. Newhook		Coke Oven Tech.

Carbonization Research

J.T. Price	B.Sc. (Calgary), Ph.D. (Western Ontario)	Res. Sci.
J.F. Gransden	B.Sc. (London), A.R.S.M., Ph.D. (Western Ontario)	Res. Sci.
J.G. Jorgensen	B.Sc. (Carleton)	Phys. Sci.
G.H. Dicks	Dipl. Mech. Tech. (Algonquin)	Technologist
D.D. Cameron	Dipl. Mech. Eng. (Ryerson)	Technologist
K.F. Hampel	Dipl. Ind. Chem. (Algonquin)	Technologist
M.J. Malette		Technologist
N.R. Manery	Dipl. Min. Tech. (Ste Claire)	Technologist
N.J. Ramey	Dipl. Min. Tech. (Haileybury)	Technologist

Energy Conservation Technology

A.C.S. Hayden	B.Eng., M.Eng. (Carleton), P.Eng.	Res. Sci.
S.W. Lee	B.Sc. (Rangoon), Ph.D. (McMaster)	Res. Sci.
R.W. Braaten	B.Eng. (Carleton), P.Eng.	Phys. Sci.
F. Preto	B.A.Sc. (Toronto), Ph.D. (Queen's)	Res. Sci.
M. Wiggin	B.A.Sc. (Waterloo)	Engineer
K. Tait	B.Sc., M.Sc. (London) (Interchange Canada)	Res. Sci.

Energy Conservation Technology (cont'd)

D.E. Barker		Technologist
D.C. Post	Dipl. Inst. Tech. (Algonquin)	Technologist
H.P. Raghunandan	Dipl. Mech. Tech. (Algonquin)	Technologist
T.G. Sellers		Technologist

Emerging Energy Utilization Systems

F.D. Friedrich	B.Sc. (Saskatchewan), M.Sc. (Queen's), P.Eng.	Res Sci.
E.J. Anthony	B.Sc., B.A. (open university) Ph.D. (Swansea), C.Chem.	Res. Sci.
D.L. Desai	B.E. (Sardar Patel), M.Eng. (Ottawa), P.Eng.	Engineer
I.T. Lau	B.Sc. (Cmengkunk), M.A.Sc. (Ottawa)	Engineer
V.V. Razbin	Dipl.Eng. (Sofia), M.Sc.Eng. (Carleton)	Engineer
W.J. Birtch		Technologist
D.H.J. McLaughlin		Technologist

Industrial Combustion Processes

H. Whaley	B.Sc., Ph.D. (Sheffield), P.Eng., C.Eng.	Res. Sci.
G.N. Banks	B.A. (British Columbia)	Res. Sci.
P.M.J. Hughes	B.Sc. (Waterloo), M.Sc. Mech. Eng. (Waterloo)	Res. Sci.
K.V. Thambimuthu	B.Sc. (Birmingham), M.Eng. (McGill), Ph.D. (Cambridge), C.Eng.	Res. Sci.
R.J. Philp	M.App.Sc. (Toronto), P.Eng.	Engineer
J.K.L. Wong	B.Sc. (Calgary)	Phys. Sci.
D.C. MacKenzie	Dipl. Eng. (Cambrian College)	Technologist
B.C. Post		Technologist
A. Salamon		Technologist
D.G. Savignac	Dipl.Mech.Tech. (Algonquin)	Technologist
R. Nadarajah	B.Sc. (Aston), P.Eng.	Technologist
R.J. Lacelle		Elec. Tech.

Coal and Coke Constitution

B.N. Nandi	B.Sc., M.Sc. (Calcutta), Dr.Eng. (Karlsruhe)	Res.Sci.
J.A. MacPhee	B.Sc. (St. Francis Xavier), Ph.D. (British Columbia)	Res. Sci.
L.A. Ciavaglia	B.Eng. (Carleton), P.Eng.	Phys. Sci.
B.H. Moffatt		Technologist
S.E. Nixon		Technologist

Project Monitoring and Engineering Design

S.I. Steindl	Dipl.Eng. (Budapest), M.Sc. (Queen's), P.Eng.	Engineer

Quality Assurance

R. Prokopuk	B.Sc. (Alberta)	Phys. Sci.
R.K. Jeffery		Technologist
F.L. Wigglesworth		Elec. Tech.

HYDROCARBON PROCESSING RESEARCH LABORATORY

M. Ternan	B.A.Sc. (British Columbia) Ph.D. (McGill) P.Eng.	Manager

Hydrocarbon Conversion

D.P.C. Fung	B.Sc. (British Columbia), Ph.D. (Windsor)	Res. Sci.
M. Skubnik	B.Eng., M.Eng. (Bratislava), P.Eng.	Phys. Sci.

Pyrolysis and Gasification

E. Furimsky	Dipl.Eng. (Prague), Ph.D. (Ottawa)	Res. Sci.
A. Palmer	B.Sc. (Montreal)	Res. Sci.
M.W. Channing	Dipl. Forest. Tech. (Sir Sanford Fleming)	Technologist
D. Smith	Dipl. Instr. Tech. (Algonquin)	Technologist
M. Légère	Dipl. Surv. Tech. (Ryerson)	Technologist

Analysis and Standardization

L.C.G. Janke	B.Sc. (Sir Wilfred Laurier), B.Ed. (Queen's)	Phys. Sci.
M.D. Farrell	B.Sc. (Carleton)	Phys. Sci.
J.Z. Skulski	Chem. Eng. (Wroclaw, Poland)	Chemist
J. Glasa	Cert.Matric (Bratislava)	Technologist
T.G. Moher	Dipl. Chem. Tech. (Algonquin)	Technologist
T. Psutka	B.Sc. (Carleton)	Technologist
H. Koethe	B.Sc. (Honours) (Queen's)	Technologist
D. Rioux		Technologist
M. Skaff		Technologist

Separation and Characterization Section

H. Sawatzky	B.S.A., M.S.A., Ph.D. (Toronto)	Res. Sci.
S. Coulombe	D.E.C., B.Sc., Ph.D. (Montreal)	Res. Sci.
B. Farnand	B.A.Sc., Ph.D. (Ottawa)	Res. Sci.
G. Jean	D.E.C., B.Sc., Ph.D. (Western Ontario)	Res. Sci.
P. Chantal	B.Sc., M.Sc., Ph.D. (Laval)	Res. Sci.
S.M. Ahmed	B.Sc., M.Sc. (India)	Chemist
G.T. Smiley	Dipl. Chem. Eng. (Ryerson)	Technologist
H. Barber		Technologist
T. Yoshida	B.Sc., M.Sc. (Muroran), Ph.D. (Hokkaida)	Visiting Sci.

Catalytic Hydroprocessing

J.F. Kriz	Dipl.Eng. (Prague), Ph.D. (Dalhousie), P.Eng.	Res. Sci.
M.F. Wilson	B.Sc., Ph.D. (St. Andrews)	Res. Sci.
M.V.C. Sekhar	B.Sc. (Madras), M.Sc. (ITT-Madras), Ph.D (Calgary)	Res. Sci.
C.W. Fairbridge	B.Sc., M.Sc. (Lakehead), Ph.D. (St. Andrews)	Res. Sci.
J. Monnier	B.A.Sc. (Laval), Ph.D. (McMaster), P.Eng.	Technologist
E.C. McColgan		Technologist
M.R. Fulton	Dipl. Chem. Tech. (Algonquin)	Technologist
M. Stolovitsky	Dipl. Biochem. Tech. (Algonquin)	Technologist
P.S. Soutar		

Catalysis Research

J.R. Brown	B.Sc., Ph.D. (Western Ontario)	Res. Sci.
J.Z. Galuszka	B.Sc., M.Sc., Ph.D. (Jagiellonian, Cracow, Poland)	Res. Sci.
S.H. Ng	B.Chem.Eng. (Taiwan), Ph.D. (New Brunswick), Eng., Chem.	Res. Sci.
V.M. Allenger	B.Eng. (McGill), M.A.Sc. (Ottawa)	Res. Sci.
L.E. Galbraith	B.A. (Carleton)	Technologist
M. Légère		Technologist

STAFF CHANGES

Promotions and Transfers

Adams, C.J. from RPO to CCRL

Fung, D.P.C. from ERL to RPO

St. James, J.W. from Technologist to Physical Scientist, CCRL

Retirements

Brown, G.D.

Resignations

Weatherall, D.

Margeson, J.

Rostkowski, J.

MacDonald, J.M

New Employees

Schumann, K.

Pelletier, M.

Belinko, K.

Thomas, S.

Smith, D.

Estwick, E.

Feres, V.

Nadarajah, R.

Clelland, I.

Fournier, D.

Malette, F.

APPENDIX B

REPORTS, PUBLICATIONS, PRESENTATIONS AND PATENTS

DIVISION REPORTS

JOURNAL SUBMISSIONS (J)

ERP/ERL 86-22(J)	The diffusion of liquids in pores	M. Ternan
ERP/ERL 86-23(J)	A rapid method for monitoring the hydrodeoxygenation of coal-derived naphtha	B. Farnand C. Fairbridge S. Coulombe
ERP/ERL 86-31(J)	Surface structure and oxidation reactivity of oil sand coke particles	E. Furimsky A.D. Palmer S.H. Ng C. Fairbridge
ERP/ERL 86-32(J)	Fluidized bed combustion of petroleum coke at CANMET	E.J. Anthony
ERP/ERL 86-37(J)	A rapid laboratory method to study displacement from packed beds of oil sand	J.L. Margeson V. Hornof G.H. Neale D.K. Faurshou
ERP/ERL 86-38(J)	A comment on "Catalysis by transition metal sulphides" by Harris and Chianelli	M. Ternan
ERP/ERL 86-39(J)	Hydroprocessing of oil sand- and coal-derived distillates: Summary of CANMET findings	J.F. Kriz C. Fairbridge M.F. Wilson
ERP/ERL 86-42(J)	Kinetics of coke formation in crudes and their fractions in a hydrogen atmosphere	D.K. Banerjee K.J. Laidler B.N. Nandi D.J. Patmore
ERP/ERL 86-48(J)	Catalysts supported on hydrous titanates for hydroprocessing mixtures of heavy oil and coal	J. Monnier G. Dénès J. Potter J.F. Kriz
ERP/ERL 86-52(J)	Hysteresis caused by dimensional changes of porous solids during mercury porosimetry	M. Ternan L.P. Mysak
ERP/ERL 86-55(J)	Role of iron in hydrogen sulphide removal from hot gas	E. Furimsky A. Palmer M.E. Brett R. Provencher M. Yumura
ERP/ERL 86-58(J)	Fractal description of the surface structure of coke particles	S.H. Ng C. Fairbridge B.H. Kaye

ERP/ERL 86-60(J)	Chemisorption of oxygen by coke deposited on catalyst surface	E. Furimsky D.G. Duguay J. Houle
ERP/ERL 86-62(J)	Gasification reactivity of Canadian anthracite and semi-anthracite chars	D.P.C. Fung C. Fairbridge R. Anderson
ERP/ERL 86-75(J)	Use of Boudart reaction for regeneration of hydrotreating catalysts	E. Furimsky J. Houle Y. Yoshimura
ERP/ERL 86-76(J)	Characterization of carbonaceous solids by oxygen chemisorption	E. Furimsky A. Palmer D.G. Duguay D. McConnell D.E. Henson
ERP/ERL 86-77(J)	Gas holdup in a tubular reactor at high pressure	T.J.W. de Bruijn J.D. chase W.H. Dawson
ERP/ERL 86-79(J)	Time series analysis of gamma densitometry signals	J.J. Lipsett R.D. Noble D.D.S. Liu
ERP/ERL 86-82(J)	Evaluation of potential uses for solid wastes from atmospheric pressure fluidized bed combustion of coal	E.E. Berry E.J. Anthony
ERP/ERL 86-86(J)	Measurement of density and expansion coefficient of light Arabian vacuum bottoms at high temperatures and pressures	D.D.S. Liu D.J. Patmore T.S. Yuyitung J.J. Lipsett K. Chapman
ERP/ERL 86-88(J)	Characterization of surfactants isolated from enhanced oil recovery oil-in-water emulsions	S. Coulombe B. Farnand H. Sawatzky
ERP/ERL 86-91(J)	Interpolation and differentiation of experimental data with cubic splines	M.V.C. Sekhar
ERP/ERL 86-93(J)	Characterization of naphtha produced by coal-heavy oil coprocessing	B. Farnand P. Rahimi S. Fouda
ERP/ERL 87-04(J)	Catalytic cracking of hydrotreated conventional and synthetic feedstocks	S.H. Ng L.E. Curts K.R. Dymock

ERL 87-11(J)	Study of pore structure and reactivity of Canadian coal-derived chars	S.H. Ng D.P.C. Fung S.D. Kim A. Kozak
ERL 87-18(J)	Large pore $Ni/SiO_2-Al_2O_3$ catalysts for hydrogenation of synthetic distillates: Effects of support composition and structure	M.F. Wilson P.R. Mainwaring J.R. Brown J.F. Kriz
ERL 87-20(J)	Regeneration of hydrotreating catalysts	E. Furimsky Y. Yoshimura

ORAL PRESENTATIONS (OP)

ERP/ERL 86-26(OP)	District heating-- A future in Canada?	M. Wiggin
ERP/ERL 86-27(OP)	CANMET hydrocracking and coprocessing for synthetic fuels production	P.M. Rahimi J.M. Denis
ERP/ERL 86-28(OP)	Les carburants oxygènés	R.J. Lafleur
ERP/ERL 86-36(OP)	Development of reactivity parameters for characterization of coal in fluidized bed combustion	I.T. Lau
ERP/ERL 86-73(OP)	Comparison of catalyst surface composition measured by XPS with hydrogen produced from oil sands residuum (Abstract only)	M. Ternan S. Girard J.R. Brown
ERP/ERL 86-80(OP)	Pyrolysis of an asphaltenic oil on catalyst surfaces having various acidities, (Abstract only)	M. Ternan J.F. Kriz
ERP/ERL 86-83(OP)	Coal oil coprocessing	M. Ikura
ERP/ERL 86-84(OP)	Pore structure engineered catalysis for hydrocracking heavy feeds (Abstract only)	M.V.C. Sekhar
ERP/ERL 86-90(OP)	Development of nickel catalysts for hydrogenation of synthetic fuels using deposition-precipitation methods (Abstract only)	M.F. Wilson P.R. Mainwaring J.R. Brown
ERP/ERL 86-92(OP)	Catalyst phenomena in upgrading oil sands bitumen and heavy oil (Abstract only)	M. Ternan
ERP/ERL 87-02(OP)	Valorisation des distillats de sources d'hydrocarbures non conventionnelles (Abstract only)	J. Monnier M.F. Wilson C. Fairbridge

ERP/ERL 87-06(UP)	Methane polymerization using a hollow cathode (Abstract only)	P. Meubus G. Jean
ERP/ERL 87-07(UP)	Surface chemistry and reduction of large pore Ni/SiO_2-Al_2O_3 distillate hydrogenation catalysts (Abstract only)	J.R. Brown M.F. Wilson
ERP/ERL 87-08(OP)	Influence of the acidity of fluorinated alumina catalysts on cracking activity (Abstract only)	J. Galuszka V.M. Allenger C. Fairbridge
ERL 87-13(OP)	Separation and characterization of polar materials in synthetic crude naphthas by column adsorption (Abstract only)	T. Yoshida P.D. Chantal H. Sawatzky
ERL 87-17(OP)	Flash hydropyrolysis of bituminous coking coal (Abstract only)	M. Ikura A.J. Last
ERL 87-22(OP)	Beneficiation of low-rank Canadian coals for coprocessing using oil agglomeration (Abstract only)	J.A. Mikhlin M. Ikura
ERL 87-23(OP)	Characterizing the structure of catalysts by fractal geometry (Abstract only)	C. Fairbridge B.H. Kaye
ERL 87-27(OP)	A data package for the validation of combustion simulation codes	P.M.J. Hughes F.C. Lockwood

ORAL PRESENTATIONS AND JOURNAL SUBMISSIONS (OPJ)

ERP/ERL 86-08(OPJ)	Reaction of acetylene over fluorinated alumina catalysts	V.M. Allenger C. Fairbridge D.D. McLean M. Ternan
ERP/ERL 86-12(OPJ)	Adsorption of nitrogenous-type compounds from synthetic crude fractions on various sorbents	P. Chantal S. Ahmed G. Jean H. Sawatzky
ERP/ERL 86-21(OPJ)	Improving the prformance of fluidized bed boilers at Canadian Forces Base Summerside	V.V. Razbin F. Friedrich
ERP/ERL 86-24(OPJ)	The competititve adsorption of fuel-type compounds on zeolite 13X	G. Jean P. Chantal S. Ahmed H. Sawatzky
ERP/ERL 86-35(OPJ)	Fluidized bed combustion of a high-sulphur Eastern Canadian coal	D.L. Desai E.J. Anthony F. Friedrich V.V. Razbin

ERP/ERL 86-44(OPJ)	Reverse osmosis fractionation of etherification reactor product streams during production of octane boosting gasoline additives	B. Farnand H. Sawatzky
ERP/ERL 86-46(OPJ)	A semi-quantitative XPS study of model Co/Mo-Alumina hydrotreating refinery catalysts	J.R. Brown
ERP/ERL 86-47(OPJ)	Pyrolysis of pitch from heavy oils using catalysts with various acid-base properties (Extended abstract)	M. Ternan
ERP/ERL 86-49(OPJ)	Deactivation of fluorinated alumina catalysts in acetylene polymerization	V.M. Allenger J.R. Brown D.D. McLean M. Ternan
ERP/ERL 86-50(OPJ)	Natural gas: alternative source of liquid fuels	G. Jean V. Allenger M. Ternan
ERP/ERL 86-54(OPJ)	Upgrading of synthetic naphthas by selective adsorption of heterotomic compounds on solid sorbents	P.D. Chantal S.M. Ahmed H. Sawatzky
ERP/ERL 86-57(OPJ)	Hydrocracking of gas oil from Athabasca syncrude	M.F. Wilson R. Simmons H. Notzl
ERP/ERL 86-64(OPJ)	Petrographic characterization of coprocessing residues	J. Potter W.J. MacDougall W. Dawson P. Rahimi
ERP/ERL 86-65(OPJ)	Solid sorbents can remove selectively heteromatic components from synthetic naphthas: A screening of the best sorbents (Abstract only)	P.D. Chantal S.M. Ahmed H. Sawatzky
ERP/ERL 86-66(OPJ)	Steam injection experiments in a scaled model for a marginal reservoir (Abstract only)	M.L. Proctor A.E. George S. Farouq Ali
ERP/ERL 86-67(OPJ)	Steam injection strategies for thin bottom water reservoirs (Abstract only)	M.L. Proctor A.E. George S. Farouq Ali
ERP/ERL 86-68(OPJ)	The effect of oxygen functional groups in different rank coals on reactivity and its relation to plasticity (Abstract only)	B.N. Nandi J.A. MacPhee D.J. Patmore J.M. Denis

ERP/ERL 86-69(OPJ)	Development of jet fuels from oil sands	M.F. Wilson I.P. Fisher
ERP/ERL 86-71(OPJ)	Influence of coal properties on carbon loss during combustion (Abstract only)	B.N. Nandi G.K. Lee J.A. MacPhee
ERP/ERL 86-81(OPJ)	Comparison of detectors for size exclusion chromatography of heavy oil related samples	S. Coulombe
ERP/ERL 86-87(OPJ)	Kinetics and thermodynamics of hydrotreating synthetic middle distillates	I.P. Fisher M.F. Wilson
ERP/ERL 87-01(OPJ)	Combustion performance, sulphur capture and vanadium balance trials with syncrude petroleum coke in a circulating fluidized bed combustor	D.L. Desai F. Engstrom W. Alderton S.H. Vayda C.E. Wood F. Friedrich
ERP/ERL 87-03(OPJ)	Progress in Canada's coal liquid fuel program: 1971 to 1987	H. Whaley P.J. Read K.V. Thambimuthu
ERP/ERL 87-09(OPJ)	The uses and morphology of atmospheric fluidized bed combustion wastes from Canada's first industrial AFBC	E.J. Anthony E.E. Berry D.P. Kalmanovitch
ERP/ERL 87-10(OPJ)	Calcium sulphide formation in solid wastes from circulating fluidized bed combustors	E.J. Anthony J. Stephenson A. de Iribarne
ERL 87-12(OPJ)	Future technology needs for Canadian fossil fuel development	D.A. Reeve
ERL 87-14(OPJ)	Developments in atomizer and burner design for coal water mixture combustion	K.V. Thambimuthu H. Whaley G.K. Lee
ERL 87-15(OPJ)	Mechanism of atomization of coal-water mixtures	K.V. Thambimuthu N.S.H. Stover
ERL 87-16(OPJ)	Preferential adsorption and selective permeation of alcohol/hydrocarbon mixtures in reverse osmosis (Abstract only)	B.A. Farnand H. Sawatzky
ERL 87-19(OPJ)	Treatment of synthetic crudes with metal chlorides and carbonyls (Abstract only)	K.R. Dymock H. Sawatzky
ERL 87-21(OPJ)	Catalyst deactivation in acetylene polymerization	V.M. Allenger J.R. Brown D. Clugston D.D. McLean M. Ternan

ERL 87-24(OPJ)	Characterization of large pore nickel-silica hydrogenation catalysts by XPS/SAM (Abstract only)	J.R. Brown M.F. Wilson U. Antinluome
ERL 87-25(OPJ)	UHV-compatible high pressure mini-reactor for in situ catalyst characterization (Abstract only)	J.R. Brown L. Coatsworth N.S. McIntyre
ERL 87-28(OPJ)	Molybdenum catalysts supported on hydrous "titanates" for hydroprocessing mixtures of heavy oil and coal (Extended abstract)	J. Monnier C. Fairbridge J.R. Brown J.F. Kriz

TECHNICAL REPORTS (TR)

ERP/ERL 86-18(TR)	Bibliography of CANMET publications in coprocessing	Coal Liquefaction Section
ERP/ERL 86-25(TR)	Analysis of calcium and magnesium in solid fuel and combustion products using atomic absorption spectrophotometer	R.K. Jeffrey
ERP/ERL 86-29(TR)	Energy Research Laboratories Annual Report 1985/86	J.L. Harcourt
ERP/ERL 86-33(TR)	Contract R&D technically administered by the Energy Research Laboratories - FY 1985/86	M. Skubnik
ERP/ERL 86-34(TR)	An evaluation of the uses and morphology of atmospheric fluidized bed combustion wastes from CFB Summerside AFBC boilers	E.E. Berry E.J. Anthony D. Kalmanovitch
ERP/ERL 86-45(TR)	Description of the Mark II atmospheric fluidized bed combustor at the Combustion and Carbonization Research Laboratory	E.J. Anthony D.L. Desai F. Friedrich D. Smith
ERP/ERL 86-55(TR)	The presence of calcium sulphide in solid wastes from circulating fluidized bed combustors	E.J. Anthony
ERP/ERL 86-59(TR)	Estimation of superficial gas velocity in a pilot plant operation	D.D.S. Liu
ERP/ERL 86-70(TR)	Gas sampling at the Point Tupper AFBC facility	E.J. Anthony M. Couturier
ERP/ERL 86-72(TR)	Methods for determining pellet volumes and effect on free swelling indices	J.T. Price J. MacDougall R. Villeneuve J.F. Gransden

ERP/ERL 86-74(TR)	Combustion trials with Syncrude coke in a pilot scale atmospheric bubbling fluidized bed	E.J. Anthony D.L. Desai F. Friedrich
ERP/ERL 86-78(TR)	Size exclusion chromatography for characterization of heavy oil/bitumen vacuum bottoms as feedstocks for coprocessing	P.M. Rahimi J.F. Kelly
ERP/ERL 86-85(TR)	Derivation of a comprehensive mathematical model for fluidized bed coal combustion	F. Preto H.A. Becker
ERL 87-26(TR)	Progress report - Hydrocarbon Conversion Section - 1986	Staff (HCS)

INVESTIGATION REPORTS

ERP/ERL 86-30(IR)	Preliminary report on the comparative combustion properties of raw and washed Price mine coal	G.N. Banks J.K. Wong H. Whaley
ERP/ERL 86-56(IR)	Final report on the comparative combustion properties of raw and washed Prince mine coal	G.N. Banks J.K.L. Wong H. Whaley
ERP/ERL 86-89(IR)	Comparative combustion properties of raw and washed Minto coals	G.N. Banks J.K.L. Wong H. Whaley
ERP/ERL 87-05(IR)	Oil shale R&D in CANMET update	E. Furimsky

RESEARCH REPORTS (R)

ERP/ERL 86-16(R)	The design and development of an optical diagnostic system for the measurement of gas temperature and species concentration	P.M.J. Hughes T. Parameswaran
ERP/ERL 86-43(R)	A data package for the validation of a computer model of the CCRL tunnel furnace facility	P.M.J. Hughes

INTERNAL REPORTS (INT)

ERP/ERL 86-01(INT)	Gasification reactivities of Quinsan coal	A. Palmer M. Channing E. Furimsky
ERP/ERL 86-02(INT)	The selective removal of nitrogen compounds using zeolite 13X: A study of interactions on the adsorption of model nitrogen compounds - A progress report	S.M. Ahmed P.D. Chantal

ERP/ERL 86-03(INT)	Datalogging software for CANMET bench autoclave hydrocracking unit (Version 1.2) - Operating and instruction manual	R. St. Louis
ERP/ERL 86-04(INT)	Material balance calculations and improvements for the CANMET hydrocracking pilot plant product yield data	J.D. Chase
ERP/ERL 86-05(INT)	Preparation of solid adsorbents for hot-gas clean-up - Part I - Northern Pigment Ltd. materials	A. Palmer M. Légère E. Furimsky
ERP/ERL 87-01(INT)	Hydrotreatment of coal-derived middle distillates with catalysts supported on zeolites or titania	J. Monnier
ERL 87-02(INT)	Preparation of solid adsorbents for hot gas clean up - Part 2 - Alcan International Ltd. materials	A. Palmer M. Légère E. Furimsky

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APPLIED FOR

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Brown, J.R., McIntyre, N.S. and Johnston, D.D. "Cobalt-molybdenum thin film catalysts for hydrodesulphurization of gaseous hydrocarbon mixtures" Kirby, Shapiro, Eades and Cohen, File 25764.

Brown, J.R., Coatsworth, L.L. and Schmidt, I.S. "Vacuum transfer vessel", Kirby, Shapiro, Eades and Cohen File 25766.

Farnand, B.A., Matsuura, T., and Sourirajan, S. "Fabrication of reverse osmosis membrane from cellulose material", CPDL File No. 265-7931-1.

Farnand, B.A., Poirier, M.A. and Sawatzky, H. "Process for selective removal of emulsion stabilizers from bitumen water emulsions", Canadian Serial No. 473,496, Feb. 4, 1986, U.S. Serial No. 737,422, May 24, 1985.

Farnand, B.A. and Sawatzky, H. "Reverse osmosis fractionation of petroleum and synthetic crude distillates", CANMET Case 43.

Farnand, B.A. and Sawatzky, H. "Membrane separation process for the removal of methanol from hydrocarbon mixtures including oxygenates", CANMET Case 49.

Farnand, B.A. and Chase, J.D. "A combined methanol-acid membrane separation process", Patent Agent's file 25817.

Mikhlin, J.A., Ikura, M., Kelly, J.F., Capes, C.E. and Chamberlain, J.F. "Coal agglomeration with heavy hydrocarbon oils", Kirby, Shapiro, Eades, and Cohen File 24645.

Razbin, V.V., Desai, D.L. and Friedrich, F.D. "System for ash reinjection in bubbling-bed fluidized bed combustor", Canadian Serial No. 505,921, April 4, 1986.

APPENDIX C

REPRESENTATION ON TECHNICAL COMMITTEES

INTERNATIONAL

AIR POLLUTION CONTROL ASSOCIATION
- APCA TS-2.3, Residential Fuel Combustion (chairman)..... A.C.S. Hayden
- APCA TS-2.2, Industrial Fuel Combustion (secretary)..... A.C.S. Hayden
- APCA Ottawa Chapter (secretary)..... S.W. Lee
- APCA Quebec Section Executive (past chairman)..... R.J. Lafleur
- Air Pollution (member at large)..... R. Prokopuk

BRITISH FLAME RESEARCH COMMITTEE (member)..... G.K. Lee

CANADA/JAPAN COAL LIQUEFACTION PROGRAM (Canadian coordinator) D.A. Reeve
- Working Group (secretary)..... M. Ikura

FUEL (London) (Regional editor)
- International Editorial Board (Canadian editor)..... A.E. George

INTERAGENCY GROUP
- R&D for Wood Combustion (member)..... A.C.S. Hayden

INTERNATIONAL CONFERENCE ON COAL SCIENCE
- Organizing Committee (Canadian representative)..... J.T. Price

INTERNATIONAL COMMITTEE ON COAL PETROGRAPHY
- Petrography (working member)..... B.N. Nandi
- Petrography of Organic Sediments (member)..... B.N. Nandi
- Subcommittee on Industrial Application of Coal Petrography (member)..... B.N. Nandi

INTERNATIONAL COMMITTEE ON COAL RESEARCH (member)..... D.A. Reeve

INTERNATIONAL COMMITTEE ON FUELS AND LUBRICANTS (member)..... S. Coulombe

INTERNATIONAL CONGRESS ON CATALYSIS (1988)
- Advertising and Publications Committee (chairman)..... M. Ternan
  (member)..... J. Monnier
- Technical Program Committee (members)..... J.F. Kriz
  ..... J.R. Brown

INTERNATIONAL DISTRICT HEATING AND COOLING ASSOCIATION
- International Relations Committee (chairman)..... M. Wiggin

INTERNATIONAL ENERGY AGENCY
- Fossil Fuels Working Party (member)..... D.A. Reeve
- Coal Research Executive Committee (member)..... D.A. Reeve
- Coal-liquid Mixture Implementing Agreement..... H. Whaley
- Atmospheric Fluidized Bed Combustion Agreement..... F.D. Friedrich
  ..... E.J. Anthony
- Low NO_x Coal Combustion of Pulverized Coal Agreement.... G.K. Lee
- Coal Combustion Sciences Implementing Agreement..... G.K. Lee
  ..... H. Whaley
  ..... P.M.J. Hughes

District Heating Implementing Agreement..... M. Wiggin
Advanced Heat Pump Implementing Agreement..... M. Wiggin

INTERNATIONAL FLAME RESEARCH FOUNDATION
Aerodynamics Panel (member)..... H. Whaley
Flame Chemistry Panel (member)..... E.J. Anthony
Joint Committee (member)..... G.K. Lee
Pulverized Coal Panel (member)..... H. Whaley
Oil and Gas Panel (member)..... A.C.S. Hayden

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)
ISO/TC-27 Solid Mineral Fuels Canadian Advisory Committee (chairman)..... L. Janke
ISO/TC-27/SC-2 Brown Coals & Lignites (secretary)..... L. Janke
(member at large)..... R. Prokopuk
ISO/TC-27/SC-2/WG-15 Coal Abrasion (member)..... R. Prokopuk
ISO/TC-27/SC-3 Coke (member)..... J.F. Gransden
ISO/TC-27/WG-12 Plasticity (member)..... T.A. Lloyd
ISO/TC-102/SC-3 Physical Testing of Iron Ores (chairman). J.T. Price
ISO/TC-109 Domestic Oil Burners (member)..... A.C.S. Hayden
ISO/TC-146/SC-1 Air Quality - Stationary Source Emissions (member)..... H. Whaley

INTERNATIONAL SOCIETY FOR CHEMICAL REACTION ENGINEERING
Canadian International Symposium on Chemical Reactor Engineering (1990) Organizing Committee (member)..... J.F. Kelly

NORTH ATLANTIC TREATY ORGANIZATION (NATO)
NATO Advanced Study Institute on Chemical Reactor Design and Technology, London, Ontario (1985) Organizing Advisory Committee (member)..... M. Ternan

SWEDEN/CANADA MEMORANDUM OF UNDERSTANDING ON ENERGY CONSERVATION TECHNOLOGY
District Heating Coordination..... M. Wiggin

US/CANADA INTERAGENCY WOOD COMBUSTION
Research Group (member)..... A.C.S. Hayden

US/CANADA MEMORANDUM OF UNDERSTANDING FOR COOPERATION ON RESEARCH AND DEVELOPMENT IN TAR SANDS (OIL SANDS) AND HEAVY OIL
Executive Committee (Canadian chairman)..... D.A. Reeve
(Canadian secretary)..... A.E. George
(Canadian member)..... H. Sawatzky
Technical Committee for Annex I (members)..... H. Sawatzky
..... R. Lafleur

US/CANADA MEMORANDUM OF UNDERSTANDING ON ENERGY R&D
Management Committee (member)..... D.A. Reeve

UNITED NATIONS INFOTERRA INTERNATIONAL DIRECTORY OF SOURCES
(environmental expert member)..... R. Prokopuk

WOOD HEATING ALLIANCE
- Engineering Committee (member)..... A.C.S. Hayden
- Emissions Testing (member)..... R.W. Braaten

UNITED STATES OF AMERICA

AMERICAN SOCIETY OF MECHANICAL ENGINEERS
- Air Pollution Control Division General Committee (member)..... H. Whaley
- Combustion and Fuels Technology Research Committee (member)..... G.K. Lee
- Research Committee on Corrosion and Deposits from Combustion Gases (member)..... G.K. Lee
- Honors and Awards Committee, Papers Review, Fuels Division (member)..... H. Whaley
- Air Pollution Control Division, Papers Review Committee (member)..... H. Whaley
- American Power Conference Organization Committee (member)..... H. Whaley
- Percy Nicholls Award Committee (member)..... G.K. Lee

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)
- Committee on Standards (member)..... L. Janke
- Committee D-2 Petroleum Products and Lubricants (member)..... R.J. Lafleur
- Committee D-5 Membership Secretary..... L. Janke
- Committee D-5 Executive (member)..... L. Janke
- Committee D-5 (member)..... M.D. Farrell
- Committee D-5 Coal, Coke, Gaseous Fuels (member at large) R. Prokopuk
- Committee D-32 Catalysis (members)..... C. Fairbridge
  ..... S.H. Ng
- Committee D-34 Waste Disposal (member)..... E.J. Anthony
- Committee D-38 Utilization of Waste Materials (member)... E.J. Anthony
- Committee D-22 Environmental Monitoring and Assessment (member)..... R. Prokopuk
- Committee E-42 Surface Spectroscopy (member)..... J.R. Brown
- Subcommittee D-5-07 Physical Properties of Coal (member)..... T.A. Lloyd
- Subcommittee D-5-22 Physical Testing of Coke (member).... T.A. Lloyd
- Subcommittee D-5-28 Petrographic Analysis of Coal (members)..... B.N. Nandi
  ..... J.C. Jorgensen
- Thermodynamic Performance of Solid Fuel Appliances..... R.W. Braaten

NATIONAL ENGINEERING FOUNDATION
- Fuels for Tomorrow Conference Organizing Committee (member)..... G.K. Lee
- Fouling and Slagging from Fuel Impurities Conference Organizing Committee (member)..... G.K. Lee

UNITED STATES OF AMERICA FOREST PRODUCTS RESEARCH
Society Editorial Review Board (member)..... D.P.C. Fung

UNITED STATES DEPARTMENT OF ENERGY
CLM Standards and Practices Committee (member)..... H. Whaley
CLM Combustion Subcommittee (chairman)..... H. Whaley

CANADA - FEDERAL

CANADIAN GENERAL STANDARDS BOARD
Committee 3-GP, Petroleum Test Methods Subcommittee (member)..... M.F. Wilson
Committee on Middle Distillate Fuels (member)..... A.C.S. Hayden
Subcommittee on Heating Fuels (chairman)..... A.C.S. Hayden
Committee on Gasoline and Alternative Automotive Fuels (member)..... A.C.S. Hayden
Committee on Petroleum Products (member)..... R.J. Lafleur
Committee on Test Methods (member)..... R.J. Lafleur
Committee on Identification of Medical Gas Cylinders, Pipelines and Flush-type Valves (member)..... L.P. Mysak
Committee on Pressure Gauges (member)..... L.P. Mysak

ENERGY, MINES AND RESOURCES CANADA
Alberta/Canada Energy Resources Research Fund - Waste Heat Recovery R,D and D Sub-program (member)..... M. Wiggin
Canada/New Brunswick Coal-Oil Shale Combustion Agreement
Management Committee (member)..... G.K. Lee
Technical Committee (chairman)..... F.D. Friedrich
(member)..... V.V. Kazbin
Canada/Saskatchewan Heavy Oil/Fossil Fuels Agreement
Management Committee (member)..... D.A. Reeve
Technical Advisory Committee (members)..... M.F. Wilson
..... A.E. George
Canada/Nova Scotia Power Corporation Agreement re Fluid Bed Test Facility at Point Tupper, N.S.
Management Committee (member)..... F.D. Friedrich
CANMET Hydrocracking
Liaison Committee (chairman)..... J.M. Denis
Patents and Publications Committee (member)..... J.M. Denis
Patent Coordination (representative)..... D.J. Patmore
CANMET Coprocessing Policy Committee (member)..... J.F. Kelly

ENVIRONMENT CANADA
FBC Technology Environmental Advisory Committee (member)..... E.J. Anthony

INTERDEPARTMENTAL
Committee on Buildings Energy R&D (member)..... A.C.S. Hayden
Committee on Retrofit Devices and Additives (member).... A.C.S. Hayden
Committee on Fuels and Lubricants (members)..... M.F. Wilson
..... S.W. Lee

INTERDEPARTMENTAL (cont'd)
- Committee on Liquid Fuels in Transportation (member).... A.C.S. Hayden
- Committee on Biomass R&D (member)..... A.C.S. Hayden
- Lead in Gasoline (member)..... A.C.S. Hayden
- Fuel Committee (member)..... F.D. Friedrich
- Management Committee for CANMET Hydrocracking (chairman)..... J.M. Denis
- Task Force on Stack Height Estimation (member)..... H. Whaley

NATIONAL RESEARCH COUNCIL ASSOCIATE COMMITTEE ON SCIENTIFIC CRITERIA FOR ENVIRONMENTAL QUALITY
- Committee on Emissions from Residential Combustion Appliances (chairman)..... A.C.S. Hayden

NATURAL SCIENCES AND ENGINEERING RESEARCH COUNCIL
- University/Industry Research Chair Program
  - Technical Ad Hoc Committee (chairman and member)..... J.R. Brown

CANADA - MISCELLANEOUS

AOSTRA/INDUSTRY/EMR
- Heavy Oil Pipelineability Study (member)..... A.E. George
- Technical Committee of Gregoire Lake In-Situ Steam Project (member)..... A.E. George
- Underground Test Facility (member)..... A.E. George
- Upgrader Residue Utilization Study
  - Management Committee (member)..... F.D. Friedrich
  - (alternate member)..... J.M. Denis

ATLANTIC COAL LIQUID MIXTURE WORKING GROUP (member)..... H. Whaley

CANADIAN ELECTRICAL ASSOCIATION
- Advisory Panel on Emissions Control..... G.K. Lee
- Project on Circulating AFBC Waste Characteristics (technical adviser)..... E.J. Anthony
- Project on Flame Scanners for Coal Firing Monitoring (technical adviser)..... P.M.J. Hughes

CANADIAN CARBONIZATION RESEARCH ASSOCIATION
- Board of Directors (member)..... D.A. Reeve
- (secretary)..... J.T. Price
- Technical Committee (member)..... J.F. Gransden
- (secretary)..... A.T. Lloyd

CANADIAN COAL PETROGRAPHERS GROUP (member)..... J.G. Jorgensen
(secretary)..... B.N. Nandi

CANADIAN GAS ASSOCIATION
- Standards Committee (member)..... G.K. Lee
- Seasonal Performance of Gas-Fired Appliances..... A.C.S. Hayden
- Industrial and Commercial Gas Burners..... F. Preto
- Industrial and Commercial Gas Package Furnaces/Boilers... F. Preto

CANADIAN GAS ASSOCIATION (cont'd)
- Industrial and Commercial Atmospherically-Fired Vertical Flue Boilers and Hot Water Supply Heaters (member)..... F. Preto

CANADIAN HOME BUILDERS ASSOCIATION
- Task Force on Future Space Conditioning Systems (member)..... A.C.S. Hayden
- Committee on Controlled Ventilation and Heat Recovery (member)..... A.C.S. Hayden
- Committee on R2000 Technical Requirements (member)..... A.C.S. Hayden
- Technical Research Committee (members)..... A.C.S. Hayden
  ..... F. Preto

CANADIAN INSTITUTE OF ENERGY (director)..... E.J. Anthony
- Ottawa Branch (treasurer)..... E.J. Anthony
- Ottawa Branch Executive Committee (director)..... S.W. Lee

CANADIAN SOCIETY FOR CHEMICAL ENGINEERING
- Ottawa-Hull Section Executive (past chairman)..... M.I. Ikura
  (chairman)..... J. Chase
  (vice-chairman)..... V. Allenger
  (program chairman)..... V. Allenger
  (secretary)..... J. Monnier
- Continuing Conference Program Subcommittee Local Section (representative)..... J.F. Kriz

CANADIAN STANDARDS ASSOCIATION
- Committee on Oil Heating Systems (member)..... A.C.S. Hayden
- Subcommittee on Chimney Dampers (member)..... A.C.S. Hayden
- Air Pollution Control (executive)..... H. Whaley
- Incinerator Performance (member)..... F.D. Friedrich
- Steering Committee on Fire Safety and Combustion (member) A.C.S. Hayden
- Oil Burning Equipment (member)..... A.C.S. Hayden
- Retrofitting of Oil Burners (member)..... R.W. Braaten
- Sampling Emissions and Measurements (chairman)..... H. Whaley
  (member)..... R. Prokopuk
- Emissions and Efficiency of Solid Fuel Appliances (member)..... R.W. Braaten
- Committee on Energy Evaluation of Houses (member)..... A.C.S. Hayden
- Subcommittee on Measurement Techniques (chairman)..... R.W. Braaten
- Subcommittee on Analytical Techniques for Housing (member)..... A.C.S. Hayden
- Task Group on Controlled Ventilation in Housing (member)..... A.C.S. Hayden
- Committee on Ventilation in New Housing (member)..... A.C.S. Hayden
- Installation Code for Solid Fuel Appliances (member)..... R.W. Braaten
- Committee on Wood-Fired Appliances (member)..... R.W. Bratten
- Committee on Solid Fuel-Fired Space Heaters (member)..... A.C.S. Hayden
- Committee on Energy Evaluation of Houses (member)..... A.C.S. Hayden
- Committee on Masonry Chimneys and Fireplaces (member).... A.C.S. Hayden
- Executive Management Committee on Venting Systems (members)..... A.C.S. Hayden
  ..... F. Preto

CANADIAN SYMPOSIUM ON CATALYSIS (10th)
(session organizer and co-chairman)..... J.R. Brown

CANADIAN SYMPOSIUM ON SURFACE SCIENCE (14th)
Surface Canada 88 (session organizer and co-chairman).... J.R. Brown

CHEMICAL INSTITUTE OF CANADA
Catalysis Division (secretary-treasurer)..... J.F. Kriz
Executive Committee (member)..... J.R. Brown
Ottawa-Hull Section Executive Committee
(ex-officio member)..... J. Monnier
Surface Science Division (member)..... J.R. Brown

FERROUS INDUSTRY RESEARCH ASSOCIATION
Technical Committee (member)..... C.J. Adams

HOUSING AND URBAN DEVELOPMENT ASSOCIATION OF CANADA (HUDAC)
Future Space Conditioning Requirements (chairman)..... A.C.S. Hayden
Controlled Ventilation and Heat Recovery (member)..... A.C.S. Hayden
Technical Research Committee (member)..... A.C.S. Hayden

NATIONAL HEAT PUMP COORDINATING COMMITTEE (chairman)..... M. Wiggin

PROFESSIONAL INSTITUTE OF THE PUBLIC SERVICE
Committee on Energy Research and Development (chairman).. M. Wiggin

UNDERWRITERS LABORATORIES OF CANADA/CANADIAN STANDARDS ASSOCIATION
Joint Committee on Wood Burning Appliances (member)..... A.C.S. Hayden

APPENDIX D

CONTRACTS, RESEARCH AGREEMENTS AND COST RECOVERY WORK

CONTRACTS

Contract title	Contractor	Scientific authority	Status
Compositional analysis of hydro-treated middle distillates from synthetic crudes by mass spectrometry	Petro-Canada Inc.	M. Wilson	In progress
Characterization of virgin and hydrogenated liquids from spouted bed pyrolysis of Canadian coals	University of British Columbia	M. Skubnik	Completed
Development of rapid GC/MS method using a Finnigan 3400 GC/MS instrument for type characterization of hydrocarbons	Zenon Environmental Inc.	R. Lafleur	Completed
Analyses of synthetic crude middle distillate fractions by C-13 NMR	Carleton University	M. Wilson	In progress
Préparation de nouveaux catalyseurs à base de métaux supportés sur ZSM-5 pour la désoxygenation de composés organiques	Laval University	J. Monnier	Completed
Upgrading of synthetic crude distillates with commercial hydrotreating catalysts	Stearns Catalytic Ltd.	M. Sekhar	Completed
Primary thermal upgrading of residua to transportation fuels	Petro-Canada Inc.	D. Fung	Completed
Dearomatization of synthetic crude	University of Ottawa	J. Kriz	In progress
Development of metal cluster catalyst for conversion of middle distillate fractions of synthetic fuels	University of Toronto	M. Wilson	In progress
The degradation study of metals-tolerant fluid catalytic cracking catalyst by molecular probes	Petro-Canada Inc.	S. Ng	In progress
Preparation and catalytic activity of supported group V B and VI B metal clusters	University of Calgary	C. Fairbridge	In progress

Contract title	Contractor	Scientific authority	Status
Experimental evaluation of catalyst deactivation caused by asphaltene adsorption	New Grade Energy Inc.	M. Sekhar	In progress
Catalytic hydrocracking of heavy oils in a layered fixed bed	New Grade Energy Inc.	J. Kriz	In progress
Development and evaluation of catalysts for hydrogenation of raw Cold Lake pitch	Guelph Chemical Laboratories Ltd.	M. Ternan	In progress
The separation of saturates and aromatics from syncrude middle distillates	Petro-Canada Inc.	S. Coulombe	Completed
Reverse osmosis separation of model compounds in heptane and toluene solutions	Zenon Environmental Inc.	B. Farnand	Completed
Selective identification of olefins and paraffins in middle distillates of synthetic crude oils	Petro-Canada Inc.	S. Coulombe	Completed
Analytical methods development and characterization requirements for projects on resource characterization	Alberta Research Council	R. Lafleur	In progress
A study into the separation of nitrogenous materials from naphtha fractions	Cambrian Engineering Group Ltd.	G. Jean	Completed
Segregation of problematic components in synthetic hydrocarbon fuel fraction using membrane separation technologies such as reverse osmosis	Memtek Corporation	B. Farnand	Completed
Adsorption of nitrogen compounds	Laval University	G. Jean	Completed
Quality and applications of asphalt derived from upgraded heavy crude	Esso Petroleum Canada	H. Sawatzky	Completed
Selective extraction of nitrogen constituents from fluid catalytic cracking feedstocks	Petro-Canada Inc.	P. Chantal	In progress

Contract title	Contractor	Scientific authority	Status
Processability and reactivity of heavy ends	Petro-Canada Inc.	S. Coulombe	In progress
Membrane processing of oil field produced water for enhanced oil recovery (EOR) steam generation	Zenon Environmental Inc.	B. Farnand	Completed
The effect of nitrogenous concentrates from synthetic crude on asphalt blends	Petro-Canada Inc.	H. Sawatzky	Completed
Detailed study of the influence of experimental conditions on retention time in size exclusion chromatography of bitumens/heavy oils/asphaltenes	Guelph Chemical Laboratories	S. Coulombe	Completed
Separation of sulphurous compounds in synthetic crude fractions	Geotechnical Resources Ltd.	P. Chantal	In progress
Separation and characterization of surfactants present in emulsions in enhanced recovery process	C.A. Shook Consulting Ltd.	S. Coulombe	In progress
Reverse osmosis separation of methanol from ethers and unreacted olefins	Zenon Environmental Inc.	B. Farnand	In progress
A techno-economic evaluation of conventional, synthetic and oxygenated gasoline blending components	Petro-Canada Inc.	H. Sawatzky	In progress
Development of a process for treating oil-water-mineral emulsions from in-situ recovery operations	Zenon Environmental Inc.	H. Sawatzky	Completed
Processing studies of bitumens/heavy oils produced by recovery methods of diverse nature	Saskatchewan Research Council	H. Sawatzky	In progress
The conversion of methane over selected catalysts	Petro-Canada Inc.	V. Allenger	Completed

Contract title	Contractor	Scientific authority	Status
Product optimization of the direct conversion process of natural gas to methanol by controlled oxidation	University of Manitoba	D. Fung	Completed
Project Gasolsyn	Concordia University	G. Jean	Completed
Investigation of process conditions for the synthesis of liquid distillates from light olefins and methanol	Petro-Canada Inc.	B. Farnand	In progress
Thermally coupled pressure swing adsorption for natural gas conversion to liquid fuels	Highquest Engineering Inc.	D. Liu	Completed
Conversion of methane to methanol using methanotrophs	Gemini Biochemical Research Ltd.	D. Fung	Completed
Methane conversion using a hollow cathode	University of Quebec	G. Jean	In progress
Hot gas clean up of gasification products	University of British Columbia	A. Palmer	Completed
Entrained gasification of Syncrude coke	Texaco Inc.	E. Furimsky	Completed
Gasification of Canadian anthracite coal in fluidized bed reactor	University of British Columbia	D. Fung	Completed
Preparation of oil sand coke-water slurry for entrained bed gasifier	Carleton University	A. Palmer	Completed
Pyrolysis of New Brunswick oil shale and coal in fluidized bed reactor	Research and Productivity Council	A. Palmer	Completed
Evaluation of steam additives and clay stabilizers for enhanced heavy oil recovery process	Petro-Canada Inc.	A. George	Completed

Contract title	Contractor	Scientific authority	Status
Impact of drilling and completion fluids on the productivity of heavy oil recovery processes	Petro-Canada Inc.	A. George	Completed
Steam injection experiments in scaled physical models for simulating marginal reservoirs	University of Alberta	A. George	In progress
Numerical simulation of steam injection in bitumen and heavy oil reservoirs: Phase II - Development of methodology for a 3-dimension dynamic grid simulator	University of Toronto	A. George	In progress
Steam recovery processes with addition of non-condensable gases - A mechanistic study	Geotechnical Resources Ltd.	A. George	In progress
Demonstration of Taciuk extraction/upgrading technology	AOSTRA	A. George	In progress
Residence time distribution studies for scale up of the CANMET hydrocracking process - Phase II	University of Waterloo	T. de Bruijn	Completed
Kinetic studies of coke formation in hydrocarbon fractions of different bitumens under various conditions - Phase II	University of Ottawa	B. Nandi	Completed
High temperature EPR studies of the thermolysis of heavy oil and its components	University of Guelph	D. Patmore	In progress
Biotechnological methods of upgrading bitumen, heavy oil and residue	University of Waterloo	F. Ng	In progress
Preliminary feasibility study of a rapid pyrolysis process ethylene, valuable chemical intermediates or high quality gas from CANMET hydrocracker bottoms and typical CANMET hydrocracker feedstock	Ensyn Engineering Assoc. Inc.	P. Sears	Completed

Contract title	Contractor	Scientific authority	Status
Kinetic studies of coke formation in hydrocarbon fractions of different bitumens under various conditions, Phase III	University of Ottawa	B. Nandi	Completed
Design, construction and technical development of dual energy gamma-ray densitometer	Atomic Energy of Canada Ltd.	D. Liu	Completed
Techno-economic comparison of the Sandwell Centrax solid-liquid separation process with the Kerr McGee critical solvent deashing process as part of an integrated two-stage liquefaction process	The Mitre Corporation	J. Kelly/ M. Ikura	Completed
Characterization of solid residue from coal liquefaction processes	University of Regina	W. Dawson	Completed
Liquefaction studies of Nova Scotia coals - Phase VII	N.S. Research Foundation Corp.	P. Rahimi	Completed
Hydropyrolysis of Eastern Canadian coals	Ontario Research Foundation	M. Ikura	Completed
Investigation of the use of spherical agglomeration in the beneficiation of low rank Canadian coals as an integrated part of CANMET coprocessing process	SNC Inc.	M. Ikura	Completed
Evaluation of atmospheric flash pyrolysis of coprocessing residues	University of Waterloo	S. Fouda	In progress
To develop, design, construct and install a pilot plant electronic instrumentation system, Phase I	Monenco Consultants Ltd.	J. Chase	Completed
Hydrocracking of individual components isolated from heavy oil and residual feeds	University of Sherbrooke	W. Dawson	In progress
Catalytic two-stage liquefaction of Nova Scotia coals	Nova Scotia Research Foundation Corp.	P. Rahimi	In progress

Contract title	Contractor	Scientific authority	Status
Agglomeration and liquefaction of Hat Creek coal	British Columbia Research	M. Ikura	Completed
Flash hydropyrolysis of Prince mine coal	Ontario Research Foundation	M. Ikura	In progress
Characterization of solid residues from coprocessing	University of Regina	W. Dawson	In progress
Exploratory investigation of solids removal from CANMET coprocessing residue	SNC Inc.	M. Ikura	In progress
Physical and chemical changes of treated coals	Cyclone Engineering Ltd.	S. Fouda	In progress
Mathematical modelling of co-processing kinetics	Lobbe Technologies Ltd.	S. Fouda	In progress
To revise and update instrumentation loop diagrams and panel drawings for coprocessing pilot plant	Monenco Consultants Ltd.	J. Chase	In progress
Potassium vapour impregnation of metallurgical coals	McMaster University	J. Price	Completed
Performance prediction of the CCRL tunnel furnace for coal combustion	Imperial College of Science & Technology	H. Whaley	Completed
Correlation of mineral, maceral and petrophysical characteristics of coal to beneficiation technology	Atlantic Coal Institute	C. Adams	Completed
Design, construction and commissioning of an apparatus for determination of sintering characteristics of coal ashes	PTL Research Ltd.	R. Philp	Completed
Mineral matter spatial distribution in coal as related to the suitability of micronizing techniques in coal combustion	Atlantic Coal Institute	J. MacPhee	Completed

Contract title	Contractor	Scientific authority	Status
Study on the characterization of coals using photoacoustic Fourier transform infrared spectroscopy and chemical transformation and derivation	St. Francis Xavier University	J. MacPhee	Completed
Develop a simulation model of the CFB Summerside fluidized bed combustor (FBC) steam heating plant	Queen's University	E.J. Anthony	Completed
Demonstration for in-furnace reduction of SO_x and NO_x in tangential-fired boilers	Canadian Electrical Association	G.K. Lee	Completed
Development of a high efficiency oil-fired warm air furnace and domestic water heater	Clare Brothers Ltd.	A.C.S. Hayden	Completed
A retrofit package for gas-fired furnaces, Phase III	Clare Brothers Ltd.	A.C.S. Hayden	In progress
Development of method suitable for petroleum refinery use to determine aromatics in heating oils and diesel fuels	Chemex Labs Alberta (1984) Ltd.	S.W. Lee	Completed
Development of gas-fired domestic water heater	Modern Times Auto Marine Ltd.	F. Preto	In progress
Prototyping and testing the retrofit of residential gas-fired furnaces with induced draft fans	The Conserver Group Inc.	F. Preto	Completed
Combustion, sulphur neutralization and vanadium balance tests with syncrude coke and Fort McMurray limestone in a pilot scale atmospheric recirculating fluidized bed combustor	Polymath Energy Consultants Ltd.	D. Desai	Completed
A program of pilot plant-scale R&D on bubbling bed atmospheric fluidized bed combustion	Queen's University	E.J. Anthony	Completed
Engineering evaluation of fluidized bed boiler demonstration plant at CFB Summerside, P.E.I.	Monenco Consultants Ltd.	F. Friedrich	Completed

Contract title	Contractor	Scientific authority	Status
An assessment of potential coal-water slurry atomizers and burners	Ralph Grossman Consultant	H. Whaley	Completed
Industrial scale testing of coal/water slurries in Canada - Cement Lafarge's Richmond wet process cement kiln	Canada Cement Lafarge Ltd.	H. Whaley	Completed
Combustion and performance testing of coal/water fuel at the Chatham, N.B. generating station	N.B. Electric Power Commission	H. Whaley	Completed
Combustion testing of ceramic coal-water fuel (CWF) atomizers in unit No. 1, Chatham, N.B. generating station	N.B. Electric Power Commission	H. Whaley	Completed
Combustion tests of dense coal CWF in a small tunnel furnace	Technical University of N.S.	K. Thambimuthu	In progress
Coal water fuel conversion and combustion testing in an industrial iron ore pelletizing furnace	Iron Ore Company of Canada	K. Thambimuthu	Completed
Stage combustion parameters for Atlantic coals	N.B. Electric Power Commission	G.K. Lee	Completed
IEA Coal Combustion Science, Annex II	IEA Coal Combustion Sc.-II	H. Whaley	In progress
IEA - Low NO_x Coal Combustion Agreement	IEA Low NO_x - Annex V	G.K. Lee	Completed
Bench scale evaluation of anthracite/thermal coal mixtures for a pulverized firing system	Gulf Canada Ltd.	J. Wong	In progress
To test NRC atomizer/burner system during Charlottetown CWF demonstration	NRC	K. Thambimuthu	Completed
Customer connections to district heating systems	EMR Renewable Energy Branch	M. Wiggin	Completed
Direct contact heat exchangers for heat pump application	St. Mary's University	M. Wiggin	In progress

Contract title	Contractor	Scientific authority	Status
IEA heat pump program: participation by NRC	NRC	M. Wiggin	In progress
The evaluation of zeolite and sodium hydroxide chemical heat pumps	Acres International Ltd.	M. Wiggin	In progress
A plastofrost study of Western Canadian coking coals	University of Waterloo	J. Price	In progress
Preparation of pitch-water slurry	Farrington, Lockwood Company Ltd.	A. Palmer	In progress
Identification of chemical sites on coal surfaces by SIMS, SEM-EDS and XPS	University of Western Ontario	J. MacPhee	In progress
A review of recent developments in hot gas clean up research	TransAlta Utilities Corp.	E. Furimsky	In progress
Extraction and characterization of crude oils from primary and enhanced recovery production	Alberta Research Council	R. Lafleur	In progress
Ion microscope studies of the oxidation of coal on a microscope scale, Phase III - study of coal surface by SIMS	University of Western Ontario	J. MacPhee	Completed
The conversion of synthesis gas to diesel fuel using novel catalyst CL-13	Centre de recherche industrielle du Quebec	G. Jean	In progress
Conversion of synthesis gas to diesel fuel using zeolite catalyst	Centre de recherche industrielle du Quebec	G. Jean	In progress
Natural gas conversion to liquid fuels over superacids	Guelph Chemical Laboratories	V. Allenger	In progress
Carbon molecular sieve-based synthesis catalysts for diesel fuel production	Guelph Chemical Laboratories	J. Galuszka	In progress
Low temperature Mossbauer spectroscopy of tin catalysts	Concordia University	J. Monnier	In progress

Contract title	Contractor	Scientific authority	Status
Upgrading heavy oil emulsions with carbon monoxide or synthesis gas	Petro-Canada Ltd.	T. de Bruijn	In progress
Chemical heat pump study - Phase II	Stearns Catalytic Ltd.	M. Wiggin	In progress
Departmental, environmental and socio-economic study on waste disposal	EMR Admin. Prog. FMB	F.T.T. Ng	In progress
AOSTRA industry upgrading residue utilization project	AOSTRA	A.E. George	In progress
Experimental remote sensing program to monitor frontal movements	US/Canada MOU-GLISP	A. George	Completed
Technologie des réacteurs à jet: application a l'hydrocrackage des huiles lourdes	University of Sherbrooke	W. Dawson	Under negotiation
Fluid catalytic cracking of non-conventional gas oils by an octane-enhancing catalyst and a metals-tolerant catalyst	Sheridan Technical Assoc. Inc.	S. Ng	In progress
Reforming of non-conventional or synthetic naphthas to high-octane transportation fuels	Petro-Canada Inc.	J. Kriz	In progress
Determination of Co-Mo-Al thin film catalyst activity for hydro-processing of synthetically derived distillates	University of Western Ontario	J. Brown	In progress
Shock tube combustion of aromatic and naphthenic hydrocarbons in jet fuels derived from Canadian oil sands	York University	M. Sekhar	In progress
Assessment of the potential for commercialization of a low severity catalytic hydrogenation process for middle distillate upgrading	To tender	M. Skubnik	Under negotiation
Opportunities in the catalytic conversion of natural gas to liquids	Stanford Research Institute	G. Jean	In progress

Contract title	Contractor	Scientific authority	Status
Preparation and pretreatment of trifunctional deoxygenation catalysts	Laval University	G. Jean	In progress
Application of the pseudoadiabatic catalytic reactor to the conversion of synthesis gas to blending stocks	University of Western Ontario	G. Jean	In progress
Process evaluation of an integrated retorting co-combustion system using fixed bed technology	Monenco Consultants Ltd.	M. Ternan	In progress
Process evaluation of an integrated retorting co-combustion system using spouted bed technology	Polymath Energy Consultants Ltd.	M. Ternan	In progress
Coal devolatilization in an entrained flow reactor	University of Ottawa	P.M. Hughes	In progress
Circulating bed combustion/pitch and tar	University of British Columbia	E.J. Anthony	In progress
Supply of in-bed boiler tubes for evaluation of erosion in fluidized bed boilers at CFB Summerside	MB&B Mechanical Services Ltd.	V. Razbin	Completed
Installation of new in-bed tubes in two fluidized bed boilers for DND Project - Summerside	DND CFB Summerside	F. Friedrich	Completed
Optimizing the performance of the low NO_x/SO_x burners and limestone system at CFB Gagetown	G.A. Robb Assoc.	G.K. Lee	In progress
Burner engineering design for the Wabamun demonstration of the Rockwell low SO_x/NO_x burner	TransAlta Utilities Corp.	K. Thambimuthu	Under negotiation
A feasibility study into commercial/industrial heat pumps	Enermodal Engineering Ltd.	M. Wiggin	Completed
Combustion enhancement by induced Ray/Leigh instability - Phase I	British Columbia Research	K. Tait	In progress
A comparative evaluation of hot water and steam based distribution system for district heating	IEA Consulting Group Ltd.	M. Wiggin	In progress

Contract title	Contractor	Scientific authority	Status
NRC heat pump system design, installation and performance evaluation	NRC	M. Wiggin	Completed
NRC ground source heat pump program - IEA Annex VIII	NRC	M. Wiggin	Completed
Heat pump/heat exchanger state of the art review and summary report. IEA Advanced Heat Pump Implementing Agreement	NRC	M. Wiggin	In progress
IEA district heating implementing agreement - Annex II, Advanced Fluids Project Modelling Services	Public Works Canada	M. Wiggin	In progress
Testing of advanced fluids, particularly R-113, in a high temperature steam generating heat pump	NRC	M. Wiggin	Completed
IEA - Heat pump agreement	IEA Coal Combustion Sc.-II	H. Whaley	In progress
Combustion venting failures: a systems approach	Canada Mortgage & Housing	A.C.S. Hayden	Completed
Whitehorse efficient woodstove demonstration	EMR Renewable Energy Branch	A.C.S. Hayden	Completed

RESEARCH AGREEMENTS

University	Title	Funds awarded ($K)	Contact officer
British Columbia	Coke texture and properties	12	J.T. Price
British Columbia	Heat transfer from circulating beds	10	E.J. Anthony
Sherbrooke	Asphaltenes: Structure et réactivité	12	M.A. Poirier
St. Francis Xavier	Detection/quantitation by photoacoustic FTIR spectroscopy of changes in oxygen functions of coals under mild thermolysis	10	J.A. MacPhee
Alberta	Uptimized microprocessor control of heat pump/heat storage systems	10	A.C.S. Hayden
Alberta	Pressurized core sampler for oil sands and heavy oil formations	75	D. Faurschou
Queen's	Microwave induced metal hydride catalytic hydrogenation and hydrocracking of bitumen	12	J.F. Kriz
École Polytechnique	Stockage de l'hydrogéne à l'aide d'hydrocarbures cycloparaffiniques	11.5	S. Coulombe
St. Mary's	Phase change salts for thermal storage	10.4	M. Wiggin

COST RECOVERY WORK - (NON-ROUTINE)

Job No.	Company/Project	Cost ($K)	% Recovery
025402	Quinsam Coal Ltd. Evaluation of combustion, slagging and fouling properties of raw and washed coal from Quinsam Coal property on Vancouver Island, B.C.	40.5	67%
025404	B.C. Hydro International Ltd. To conduct a seminar on coal combustion research for visiting scientists from the Electric Power Research Institute of China	8.9	79%
025405	Luscar Ltd. Evaluation of the briquetting properties of upgraded low-rank coals	5.3	75%
025406	B.C. Hydro International Ltd. Feasibility study on creation of a combustion research facility at the Thermal Power Research Institute, Xian, China	11.4	58%

COST RECOVERY WORK - (ROUTINE - INCLUDES EXCHANGE ANALYSES)

AMAX Coal Co.

Bioshell Plants:
- Lac Mégantic
- Hearst, Ont.
- Iroquois Falls

CANMET's Service Program for the Evaluation of Characterization Standards (CANSPECS)
Commercial Testing and Engineering
Department of National Defence - Coal evaluation; petroleum fuels analysis
Environment Canada - Wastewater Technology Centre
Fuels Engineering of New York
New Brunswick Electric Power Commission
National Research Council - Fuels and Lubricants Laboratory
Ontario Ministry of Natural Resources - Petroleum
Ontario Ministry of Transportation
Others (DPW, Univ. of Ottawa, CCA, DVA, private companies)
Standard Laboratories

TOTAL VALUE = $63 K

APPENDIX E

CONTACTS, MEETINGS, FIELD TRIPS, AND JOINT CONSULTATIONS

CONTACTS, MEETINGS AND FIELD TRIPS

ERL remained as the national laboratory in fossil energy technology, in particular in the areas of heavy oil and bitumen recovery and upgrading and advanced coal to electricity processes which allow coal to be burn cleanly and at increased energy conversion efficiencies. Also ERL's role in residential and industrial energy conservation technologies expanded to include heat pump and district heating technologies.

Contacts were maintained with other research organizations and private sector companies and agencies to enhance technology transfer and promote the exchange of information relating to research programs. This aspect of ERL's activities assumed a new importance with the requirement to demonstrate and achieve closer working relationships with industry. Efforts were made within the scope of these contacts to encourage increased private sector participation in research programs. Intelligence flowing from these contacts and also from international contacts, for example through direct participation by ERL scientists in International Energy Agency technology agreement, allowed ERL to provide advice to the department and to make adjustments to its program plans.

ERL scientists were active in 49 conferences across the continent and in other parts of the world at a cost of approximately $63 000.

During 1986/87 ERL hosted visits by scientific and technical personnel from many parts of the world and conducted numerous tours of its facilities. ERL remains in the forefront of energy research and cooperates with others through the exchange of information and granting programs to private industry and universities.

The research agreements and contracts awarded to industry, private consultants, and universities continued to grow necessitating continued technical supervision and travel by staff. In addition to consultations related to the contracts in Appendix D of this report, many visits were made to discuss and evaluate new proposals or to make preliminary plans for contract work in the next fiscal year. The development of the CANMET shared-cost energy conversion program, for example, required extensive contact by ERL technical and scientific staff.

On an individual basis, ERL scientists engage in external consultations through their membership in technical committees as indicated in Appendix C. Substantial contributions were made to standardization organizations such as ISO, CSA, and ASTM. The committees of these organizations include representatives from public and private sectors as well as from academic institutions.

JOINT PROVINCIAL/INDUSTRY/FEDERAL/INTERNATIONAL CONSULTATIONS

PROVINCIAL

Alberta Office of Coal Research and Technology
Alberta Oil Sands Technology and Research Authority (AOSTRA)
Alberta Power Corporation
Alberta Research Council
Atlantic Coal Institute, Sydney, N.S.
B.C. Hydro International, Vancouver
Centre de recherche industrielle du Québec
Manitoba Mines and Energy, Winnipeg
Hydro Québec
New Brunswick Department of Industry and Regional Expansion
New Brunswick Electric Power Commission
New Brunswick Research and Productivity Council
Nova Scotia Department of Energy and Mines
Nova Scotia Research Foundation, Dartmouth, N.S.
Ontario Hydro
Ontario Ministry of Energy
Saskatchewan Research Council
Saskatchewan Energy and Mines
Saskatchewan Power Corporation, Regina
Simon Fraser University, Vancouver
University of Alberta, Edmonton
University of Calgary
University of Laval
University of Ottawa
University of Saskatchewan, Saskatoon
University of Western Ontario
Whitehorse City Council
Yukon Department of Energy, Whitehorse

INDUSTRY

Alberta Energy Company Ltd., Calgary
Alcan International, Kingston, Ont.
Algoma Steel Corp., Sault Ste. Marie, Ontario
BP Canada Inc., Calgary
Breslube Enterprises, Kitchener
Canadian Carbonization Research Association
Canadian Electrical Association
Canadian Industries Limited Inc., Toronto
Canadian Liquid Air, Montreal
Canadian Natural Gas Systems, Toronto
Cape Breton Development Corporation
Coal Association of Canada
Coal Mining Research Company, Devon, Alberta
Concorde Scientific Corporation, Toronto
Consultec Limited, Toronto

INDUSTRY (cont'd)

Consumer Gas Limited, Toronto
Crown Oil Sands Energy Corp, Winterburn, Alberta
Crows Nest Resources, Calgary
Denison Mines Ltd., Vancouver
Direction de la Chimie et de la Métallurgie, Montreal
Dobrocky Seatech, Victoria, B.C.
Dofasco, Hamilton
Dome Petroleum, Calgary
E.H. Hanson & Associates, Delta, B.C.
Enviro-Sonic Technologies Inc., Vancouver
ERCO, Toronto
Esso Resources Canada Ltd., Calgary
Fording Coal Limited, Calgary
Front End Resources, Grand Forks, B.C.
Garrand Homes, Ottawa
Geotechnical Resources Ltd., Calgary
Globe and Mail Business Section, Toronto
Gregg River Mine, Hinton, Alberta
Guelph Chemical Laboratory Limited
Gulf Canada Ltd., Sheridan Park, Ontario
Heuristic Engineering Inc., New Westminister, B.C.
Institute for Chemical Science and Technology, Sarnia
Irving Oil Refinery, St. John, N.B.
LL&E Canada Ltd., Calgary
Luscar Ltd., Edmonton
Membrane Technology Consultants, Nepean, Ontario
Mitel, Ottawa
Monenco, Toronto
Murphy Oil, Calgary
McLaren Plansearch, Toronto
Norwest Resource Consultants Ltd., Calgary
Nova/Husky Research Corporation, Calgary
Ottawa Citizen
Petro-Canada
Petrosar Ltd., Corunna, Ontario
Polymath Energy Consultants Ltd.
Renzy Mines Ltd.
Sandwell-Swan Wooster Inc., Vancouver
Saskatoon Star - Phoenix
Shell Canada Research Centre, Oakville, Ontario
Sheridan Technical Association, Mississauga, Ontario
Syncrude Oil Research Department, Edmonton
Syntech, Calgary
Smoky River Coal Company, Grand Cache, Alberta
SNC Inc., Montreal
Stone and Webster Consultants, Toronto
Tech Corporation, Chetwynd, B.C.
TransAlta Utilities, Calgary
Union Gas Ltd., Chatham, Ont.
Westar Mining, Sparwood, B.C.
ZAS Technology Inc., Montreal
Zenon Environmetal, Burlington, Ont.

FEDERAL

Agriculture Canada
CBC Ottawa
CBC Whitehorse
CFB Gagetown, New Brunswick
Department of Regional Industrial Expansion
Environment Canada, Burlington
External Affairs
Health and Welfare Canada
National Research Council
Natural Sciences and Engineering Research Council

INTERNATIONAL

UNITED STATES

Advanced Fuel Research Inc., East Hartford, Connecticut
American Gas Association
American Society for Testing and Materials, Philadelphia
ARCO, South Louisiana
Battelle Laboratories, Columbus, Ohio
Centre for Research on Sulphur in Coal, Champaign, Ill.
Chevron Research Company, Richmond, California
Coalition of North Eastern Governors
Commercial Testing and Engineering Co., Lombard, Illinois
Committee on Coal Combustion Sciences, Washington
Conoco Coal Research, Pennsylvania
Cool Water Demonstration Project, Barstow, California
EER Corporation, Irvine, California
Energy Development Corporation, Pittsburgh, Pennsylvania
Engelhard Corporation, Edison, New Jersey
Exxon R&E Co., Houston, Texas
Film Tec Corporation, Minneapolis
Gas Research Institute, Chicago
Houston Lighting and Power Company, Texas
J-P Associates, Dallas, Texas
KCERL, Lexington, Kentucky
Mitre Corporation, McLean, Virginia
Minnegasco, Minneapolis, Minnesota
Mobil Research and Development Corporation, New Jersey
New Jersey Institute of Technology, Newark, N.J.
New York State Energy R&D Authority
Phibro Energy Inc., Connecticut
Polytechnique Institute, Troy, New York
Rockwell Burner Development, Canoga Park, California
South California Edison
Southern Research Institute, Mobile, Alabama
SRI International, Menlo, California
Tri State Testing, Ashland, Kentucky
TRW Inc., Redondo Beach, California
Union Carbide, Charleston, West Virginia

INTERNATIONAL (cont'd)

Universal Light and Heavy Oil Tar Sands and Coal Research Corporation
University of Kentucky, Lexington, Ky
University of Western Kentucky, Bowling Green, Ky
U.S. Environmental Protection Agency
U.S. Department of Energy
U.S. Department of State
U.S. Wood Heating Alliance
Wyoming Analytical Laboratories, Arvada, CO.

OTHERS

Advanced Institute of Science and Technology
Agency of Industrial Science and Technology, Tokyo
Amsterdam University, Netherlands
Association of Southeast Asian Nations
Central Coal Mining Research Institute, China
CERCHAR, Paris
China Electric Power Research Institute, Xian, China
Coal Mining Research Centre, Tokyo, Japan
Elkraft, Denmark
Falcon Research, Johannesburg, South Africa
Federal Institute for Geosciences and Natural Resources, Hannover, West Germany
Idemitsu Kosan KK, Calgary
Institute of Mining Research, Zimbabwe
Institute of Technology, Nagpur, India
International Energy Agency, London
Ministry of Coal, China
Mitsubishi Heavy Industries, Tokyo
National Swedish Laboratory
New Energy Development Organization, Tokyo
New Scientist Magazine
Nippon Oil and Fats Co., Japan
Nippon Steel Corporation, Kitayushu, Japan
Nuclear Research Centre, West Germany
Studsvik Emergiteknik, Sweden
Swedish State Power Board, Stockholm, Sweden
University of Zhejiang, Hangzhou, China